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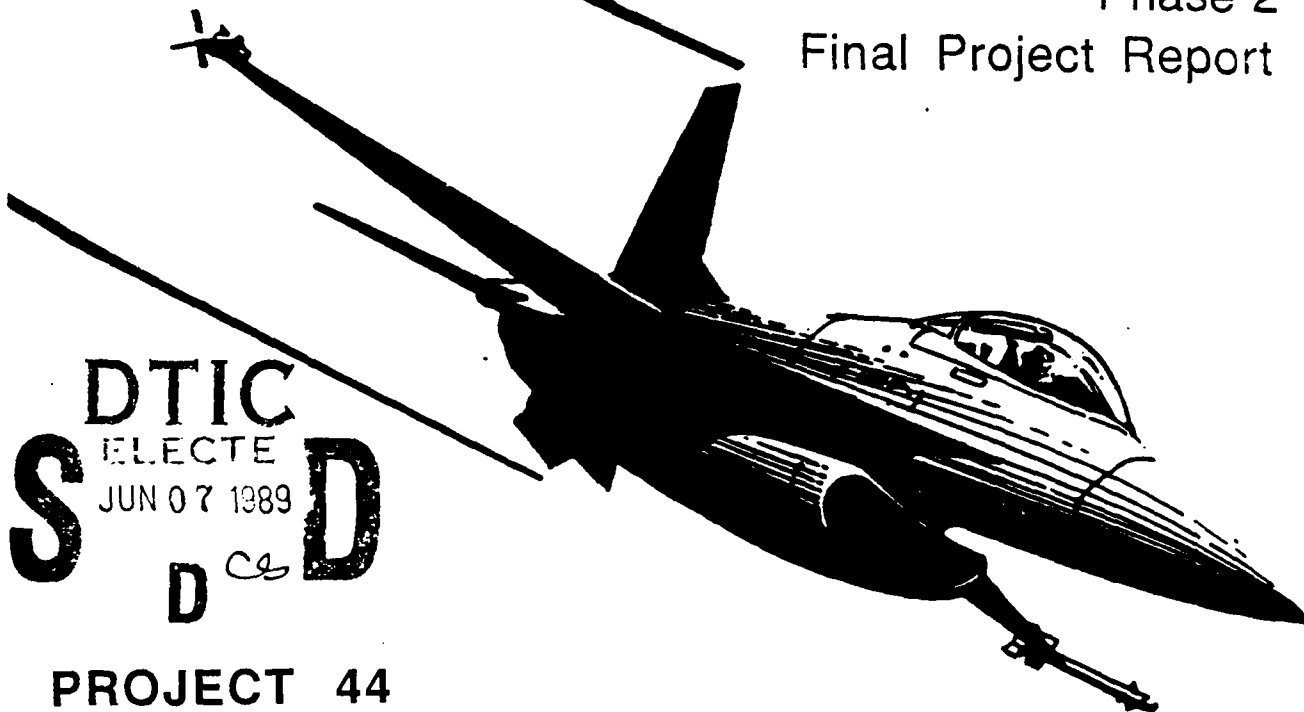
**GENERAL DYNAMICS**

**FORT WORTH DIVISION**

# **INDUSTRIAL TECHNOLOGY MODERNIZATION PROGRAM**

Phase 2

Final Project Report



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**PROJECT 44**

**MODERNIZE FACILITY EQUIPMENT  
AND PROCESSES**

**VOLUME 2 REVISION 2**

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# Honeywell

GENERAL DYNAMICS  
FORT WORTH DIVISION

MAY 1, 1988

INDUSTRIAL TECHNOLOGY  
MODERNIZATION PROGRAM

PROJECT 44

PHASE 2 FINAL PROJECT REPORT

MODERNIZE FACILITY EQUIPMENT AND  
PROCESSES

VOLUME 2 REVISION 2

AVIONICS SYSTEMS GROUP  
MILITARY AVIONICS DIVISION  
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## INTRODUCTION

### FINAL REPORTS FOR ITM PROJECT 44

### MODERNIZE FACILITY EQUIPMENT AND PROCESSES

In accordance with PO #1005262, Military Avionics Division of Honeywell herein submits to General Dynamics the Final Project Report and Final Cost Benefit Analysis Report for ITM Project 44.

The reports are contained in four (4) volumes.

- Volumes One and Two contain the Final Project Report for the project.
- Volume Three was a Supplement which was incorporated into Volumes One and Two during Revision 2.
- Volumes Four and Five contain the Final Cost Benefit Analysis Report.

The Tables of Contents and a Lists of Illustrations are organized as follows:

- For the Final Project Report, they are at the beginning of Volume One.
- For the Final Cost Benefit Analysis Report, they are at the beginning of Volume Four.

Project 44 was divided and examined as nine (9) separate Work Cells plus an Overview. The order in which the cells are presented has been standardized in each of the reports and supplement based on implementation dates (with the exception of NC Programming which is implemented concurrent with the implementation of each individual cell). The order of presentation of the cells is as follows:

1. Project Overview
2. Laser Base Cell
3. Walnut Cell
4. Sheetmetal Cell
5. Pallet Cell
6. Lamination Cell
7. Girth Ring Cell
8. Model/Short Run Shop and Flexible Machining Area  
included are the Dither Spring Cell and 1 1/2" Bar Cell
9. NC Programming
10. T-Bar Cell

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## PROJECT 44

### LAMINATION CELL

#### SECTION 1

#### INTRODUCTION

Lamination assemblies made up of individual punched nickel-iron laminations, are major components of the GG1111, GNAT, and GG4400 gyros, built in Precision Control Instruments (PCI) of Honeywell's Military Avionics Division. Flight Systems Operations (FSO) also builds lamination assemblies for the Integrated Helmet and Display Sight System (IHADSS) device. The bonding of laminations and machining of assemblies will form the basis for grouping these operations within a work cell. All of the selective parts that will compose 80 percent of this cell are piece parts and sub-assemblies having very similar operations. Lamination stacks are individually stamped or etched, laminations are epoxied or welded into an integral assembly. Magnetic characteristics can be damaged by abusive machining or handling. A two foot drop to a hard surface may destroy both the mechanical tolerance and the magnetic characteristics. Parts are generally small in size. A standard 10" X 16" X 3" divided tray will hold approximately 200 typical parts. Both visual and mechanical tolerances use extremely demanding Mechanical tolerances for concentricity, perpendicularity, run out and size tolerance, from .0002 to .0003 inches for many assemblies. Inspection for visual flaws, burrs, excessive rounding of corners, epoxy and other residues or foreign substances detectable at 10 to 20 power magnification are cause for rework or scrap for many assemblies. Cost savings will result in forming families of parts and combining new technologies for the production of lamination assemblies. Keeping the manufacturing of lamination assemblies within a work cell will improve the lead time, which also will result in a savings in inventory and material handling costs.

## SECTION 2

### PROJECT PURPOSE/OVERVIEW

\* The purpose of this project is to find a more economical way of making the stack and shaft assemblies that are used in all "iron gyros" used by the Precision Control Instruments (PCI) business group. One of the key manufacturing tasks involved is to remove the excess cement from all of the exterior surfaces of the lamination stacks. Complete removal is necessary before the application of the insulating coating, which is necessary for the wire winding that is accomplished in the gyro assembly area.

Currently, the Fabrication Facility (Fab Fac) is assembling, grinding, burring, coating, and marking the lamination assemblies in areas segregated from each other. Schedules are delayed as parts wait to be moved to their respective operations.

Using state-of-the-art technology (for removing the excess cement) along with dedicated machines (located together in a single cell configuration) will decrease the schedule time and labor time needed to build iron gyro lamination assemblies.

## SECTION 3

### TECHNICAL APPROACH

The technical approach for the Lamination Cell for Project 44 was as follows:

- Established a group of parts that have similar processes and could be grouped together in a work cell environment.
- Developed a manufacturing system which led us to search out new leading edge/state of the art equipment to optimize building the lamination assemblies.
- Selected equipment which met the need for the quantity and quality of this work cell.
- Selected vendors for specific manufacturing operational requirements for the lamination assemblies. Samples were prototyped by prospective vendors to test Plasma Etch Technology for proposed applications.
- Reviewed part sample results to be certain they performed as the vendor had stated.
- Incorporated Inspection into this work cell environment to ensure the assemblies met all Quality requirements.

## SECTION 4

### "AS-IS" PROCESS

Honeywell's Fabrication Facility (Fab Fac) currently builds lamination stacks and assemblies for the Precision Control Instruments (PCI) group, and Test Systems and Logistics Operations (TSLC). These assemblies become part of their products.

A lamination stack is made up from many flat nickel-iron punched laminations of .002 inch to .014 inch thickness. The individual laminations are heat treated for the proper magnetics and coated with epoxy adhesive. Fab Fac then stacks these individual lamination assemblies in fixtures to process or print specifications. An illustration of a Lamination Material Flow and Floor Layout is shown in Figure 4.1. The fixtures loaded with the laminations are then baked in an oven which activates and cures the epoxy coating. The fixtures are removed from the oven, cooled, and the formed lamination stack is removed. During the curing of the lamination stack, the excess epoxy flows on the exterior surfaces. This epoxy must be removed before any machining, metal finish or assembly. Currently, hand-held dental abrasive blasting equipment is used to remove all of the exterior epoxy from the lamination stack.

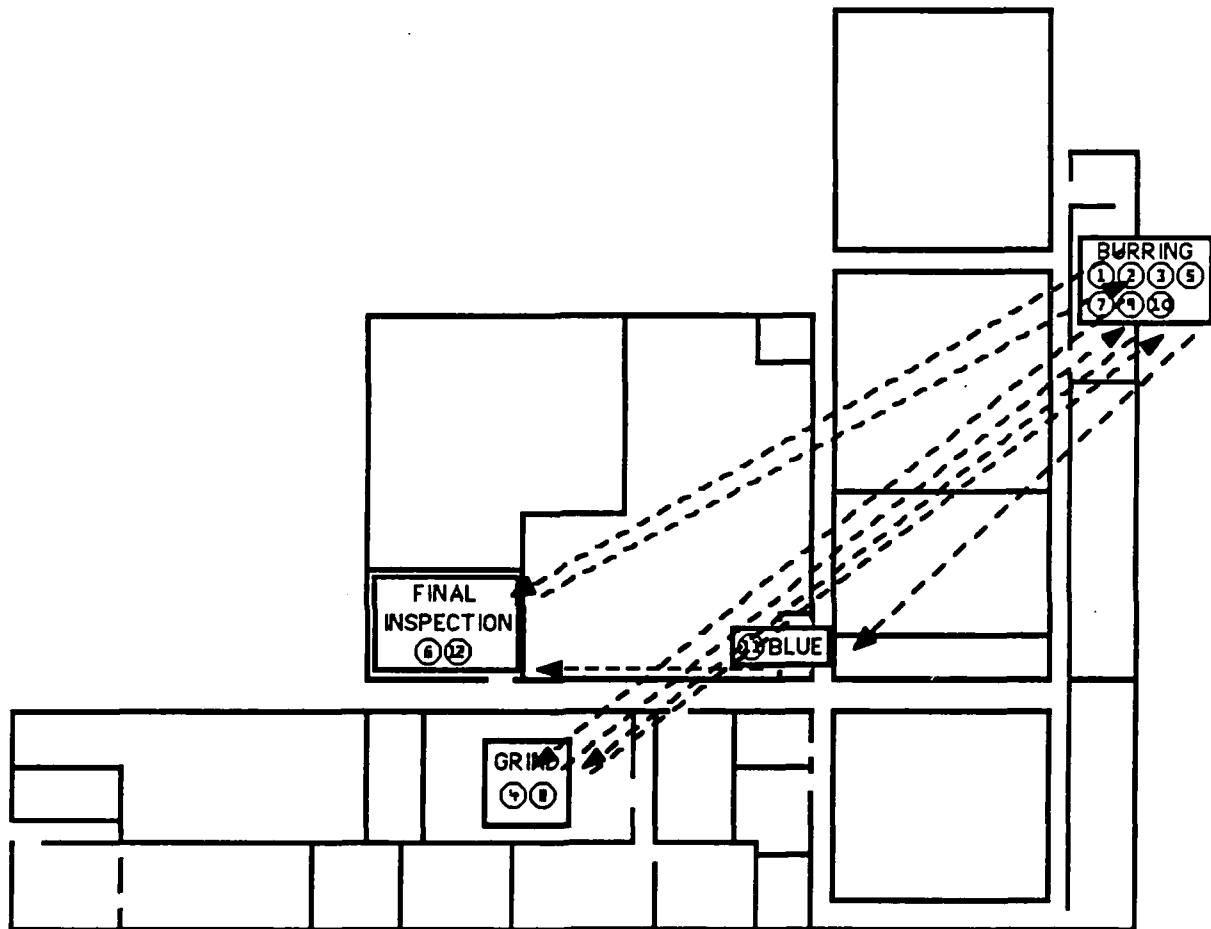
The next Fab Fac operation on most assemblies is Grinding. Currently the grinding area grinds the lamination assemblies plus all of Honeywell's other precision parts that go into building devices for the total Division. As personnel changes occur, new operators must be trained to handle the lamination stacks so they do not deteriorate the quality of the assembly. Normal hard pressure can distort the assembly out of tolerance. This grinding area is not near the stacking area. New operators must be formally trained in the importance of the magnetic properties involved. Magnetic properties can be destroyed by rough machining or operator handling. All current grinding machines are at least thirty years old and require a skilled manual set-up for each group of parts that are machined. These manual machines require constant operator attention, causing fatigue and high labor costs. Parts are then sent to another location where they are deburred and assembled into an assembly. Parts are then sent back to the Grinding Area for a straightening operation and return to be deburred again. The parts are gritblasted for adhesion prior to being coated with bluecoat (epoxy coating).

The Quality department handles all of the parts for our division and each inspector that checks the lamination stack or assembly must be trained to make sure the parts meet PCI requirements.

#### MATERIAL FLOW AND LAYOUT

The factory presently is laid out in a traditional plan which results in poor work flow (see Figure 4.1). Time is lost moving parts from one group of operators to another. Each group of operators must be trained in how to handle these Lamination Assemblies. As new employees are hired in each manufacturing location or into the positions that physically move trays of parts to the various locations, training must be given in how to handle the parts without destroying the magnetic properties of the laminated stacks.

# **LAMINATION CELL MATERIAL FLOW -- AS IS**



- |                            |                      |
|----------------------------|----------------------|
| 1. Build Lamination Stacks | 7. Assemble To Shaft |
| 2. Cure Cement             | 8. Finish Grind      |
| 3. Soda Blast              | 9. Deburr            |
| 4. Internal Grind          | 10. Grit Blast       |
| 5. Deburr                  | 11. Bluecoat         |
| 6. Inspection              | 12. Final Inspection |

Figure 4.1 "As-Is" Lamination Material Flow and Floor Layout



## SCHEDULING

Lamination stacks are built in lots of 50 to 500. Each order must be handled through many departments, causing scheduling problems for the production control department (see Figure 4.2). The current reporting system, including job paperwork, is workable. However, production control personnel must expend extra time and leg work to determine the status of an order. On-time delivery of assemblies is very important. Delays occurring in the manufacturing area could delay operations in the final gyro build department, causing missed shipment delivery to customers.

## PROCESS FLOW

The process flow of building a typical lamination assembly involves 14 steps (see Figure 4.3). These steps include:

- Count Laminations

To insure the proper amount of metal is in each stack, the laminations are counted and weighed by the operators to meet the print requirements for the stack assembly. Operators are required to wear latex finger protectors and handle the individual laminations carefully, so they do not damage or contaminate the individual laminations which have been coated with epoxy.

- Build Stacks

The individual laminations are placed in fixtures and carefully pushed into the proper alignment. It is very important that the individual laminations are not mishandled during this operation, because the stack could be misaligned and the stack would be scrapped. The top of the fixture is assembled and this pre-loads the stack of laminations with a constant pressure, which is necessary while curing the epoxy.

- Cure Cement

The fixtures loaded properly with the individual laminations are placed on racks in a preheated oven. The oven temperature and bake time is monitored to assure quality control that the epoxy will flow and adhere to each lamination, making one solid stack. The fixtures are unloaded from the oven, cooled, and disassembled. Quality control takes a sample of the cured stacks and checks them for epoxy adhesion and voids which could be between the laminations. Voids and poor adhesion are not allowed as either condition causes problems in the final build area.

- Abrasive Blast

The parts are moved to the Abrasive Blast Department to have the excess epoxy removed. There, a dental light-abrasive blasting unit is used. If an aggressive grit were used to remove the epoxy, the lamination stack would be destroyed since these stacks are made to very precision tolerances. The operators hold the lamination stacks, using rubber gloves to protect themselves, in a vented hood which pulls the spent material into a vacuum system.

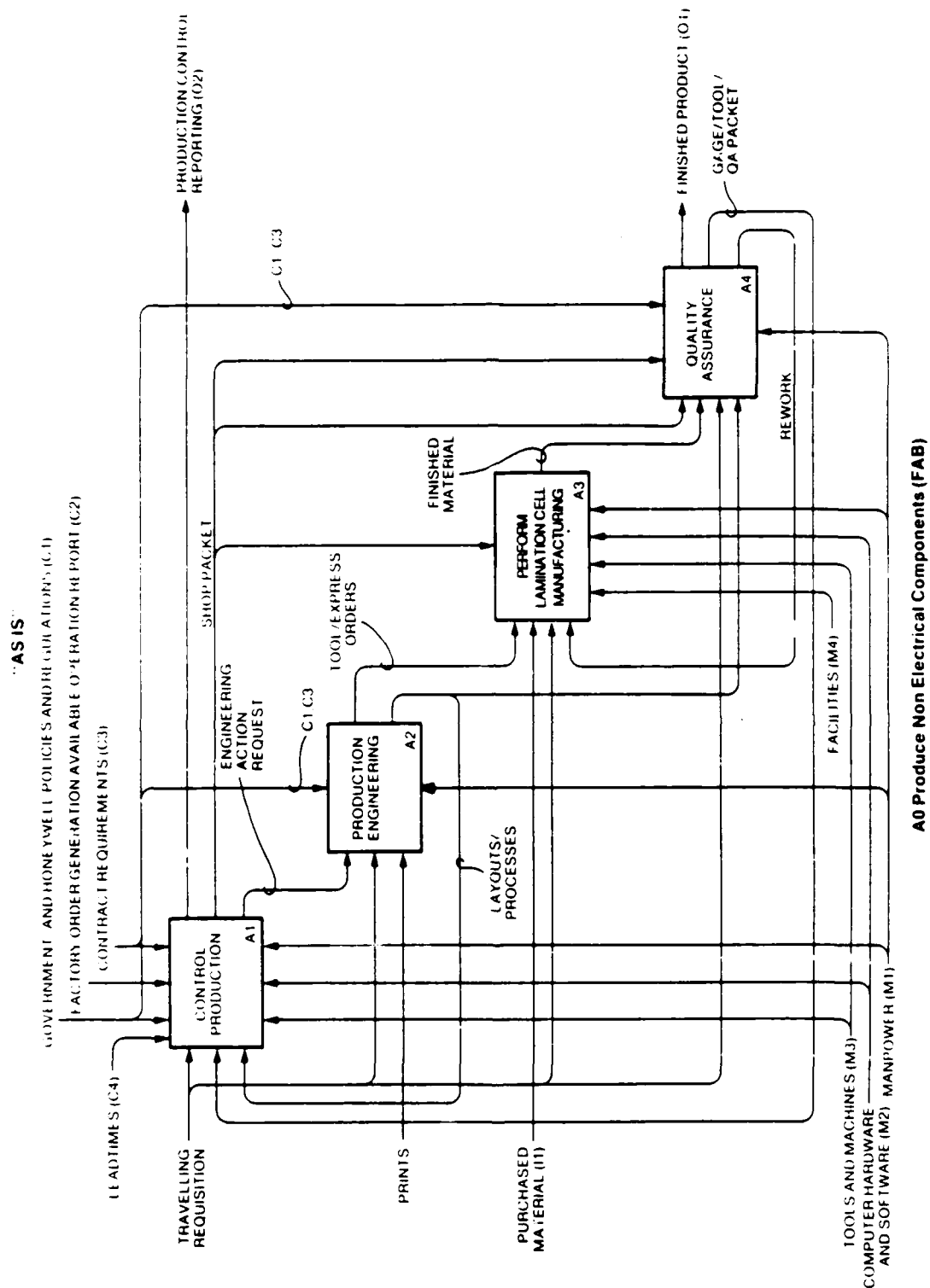


Figure 4.2 "As-Is" Lamination Workflow Diagram

## LAMINATION CELL PROCESS FLOW -- AS IS

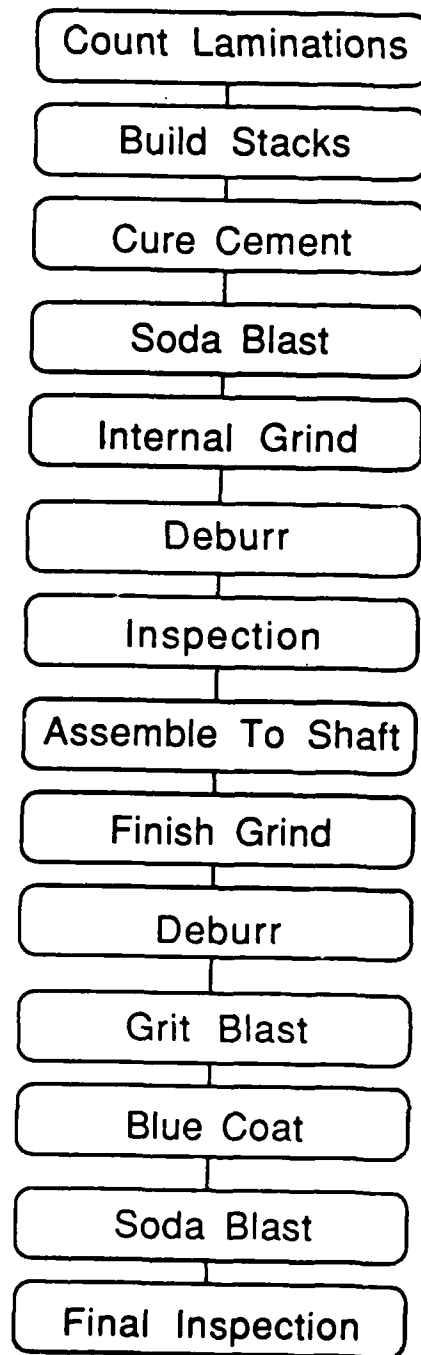


Figure 4.3 "As-Is" Lamination Process Flow

The operator holds the dental hand nozzle and directs the blast of abrasive mixed with air at the various openings of the lamination stack and removes all of the epoxy from the exterior surfaces. All of the epoxy must be removed from the exterior surfaces of the lamination stack or the blue coat, which is applied later for insulation purposes, will not flow properly.

- Internal Grind

The lamination stacks are moved to the Grinding Department for grinding the inside diameter which is necessary for installing a shaft. Each stack is loaded into a fixture that is oriented on an internal grinding machine. A grinding wheel is passed through the inside diameter enough times to enlarge the hole to meet the drawing requirements.

- Deburr

The lamination stacks are moved to the Deburring Department. The operators deburr the grinding burr that was raised by the grinding wheel when the internal diameter was enlarged. Great care is taken by the deburring operators to remove the loose burrs and not damage the parts. Operators check their work under a microscope to insure they have performed their operation properly.

- Inspection

The lamination stacks are moved to the Inspection Department. These inspectors check a sample of parts, determined by quality control, to insure the parts meet all print requirements. This is a very important step in the process. A lamination stack that does not meet all print requirements could cause serious problems in the final gyro build area. If any parts are rejected, the whole lot of parts are sent to the department which was responsible. After the responsible department sorts for the rejected parts, they rework them if possible. After this sorting and reworking, the parts are sent back to the inspection department for re-inspection.

- Assemble to Shaft

The lamination stacks are moved to the assembly area and a shaft is pressed into the stack forming a lamination stack assembly. The operator orients the shaft in the stack to meet the print requirements, and places this assembly into a fixture, located in an arbor press, and presses the shaft into the proper location.

- Finish Grind

The lamination assemblies are moved to the grinding area, for grinding the external diameter of the laminated stack. The operator loads each part on centers and grinds the external diameter to print requirements. If the laminations are ground too severely, the magnetism could be ruined and could cause problems in the final gyro build area.

- Deburr

The lamination assemblies are moved to the deburring area. These are very critical assemblies and the small hanging burrs from grinding must be removed. The operators hold the assembly into a rotating deburring brush, and the loose hanging burrs are removed. The parts are checked under a microscope to make sure all burrs are removed.

- Gritblast

The lamination assemblies are moved to the Gritblast Department. The surface of the lamination stack, which requires the insulation (bluecoat) for winding, has to be lightly gritblasted for adhesion. The operator places masks over the critical surfaces of the assemblies and very carefully gritblasts the remaining surfaces.

- Bluecoat

The lamination assemblies are moved to the bluecoat area. Bluecoat is an electrostatic coating which is used for insulating the windings, which are wound in PCI, from the lamination stack. The operator places special built masks to protect certain areas from bluecoat. Then the operator applies a thin film of bluecoat to the assembly and carefully places the parts in an oven to cure. After curing, the operator checks the bluecoat for voids or bubbles. The parts with voids or bubbles must be reworked.

- Abrasive Blast

The lamination assemblies are moved to the blast area. Some areas of the lamination assemblies which are bluecoated have to be free of bluecoat, and the operator places a mask over the assembly and removes the bluecoat with the blasting. After blasting, the operator cleans the parts and makes a final check to insure the lamination assemblies meet all print requirements.

- Final Inspection

The finished lamination assemblies are moved to the Final Inspection Department. At this point all of the Fabrication Facilities operations have been accomplished, and our Quality Control Department performs a final inspection of a sample of assemblies, that is selected by Quality Engineering. The Quality Inspection Department checks for print requirements on the complete lamination assembly. After inspection, the part is recorded and shipped to PCI for use in their final build.

## SECTION 5

### "TO-BE" PROCESS

Grouping all the machining and assembling in a work cell environment and having a single group of operators responsible for completed parts will ensure a better product to the gyro assembly area on schedule. Employees within this environment will have a better understanding of the parts, and promote communication between the operators. Scrap and rework will decrease because everyone in the cell will be familiar with all the operations and help train new operators.

A single group leader, who will oversee all of the operations, will have the responsibility to check the area for problems and contact supervision for help when needed.

#### MATERIAL FLOW AND LAYOUT

Production Control will only have to check one area to locate the parts which need special consideration for the gyro build area. Their task of part reporting will also be simplified because the part will be assembled in one area. There will be a reduction in lead time from start to finish, because the parts will not be shipped all over the machine shop for each operation, as shown in Figures 5.1 and 5.2.

#### PROCESS FLOW

Stacking and machining of the Lamination Stacks and assemblies will be similar to the present operation. The removal of excess cement will be accomplished in a vacuum oven which uses chemical gas and electronics. Parts will be hung on wire racks and the cement will be reduced to an ash. Some abrasive blasting to remove this ash will be necessary to completely clean the lamination stacks.

Parts are processed on new CNC (Computer Numerical Control) grinders which will reduce the set-up and grinding time needed. These CNC grinders will process work faster and the machine controller will compensate for wheel wear to assure accurate size on the part. When the part is finished, the machine controller will move the part to a safe unload position for the operator to unload and reload another part to be ground. While the machine is grinding, the operator has time to check dimensions and remove any small burrs from the parts.

After grinding, the lamination stacks are assembled with shafts and returned to the grinding area for finish grinding. Some of the stacks have special deburring requirements. All of these special operations will still take place within this work cell.

Blue coating of the finished lamination stack is in the metal finish department and will continue as in the past. Combining this area within this work cell is not practical. The Metal Finish area for cleaning and coating needs an environment which would be difficult and costly to provide within the laminations work cell environment.

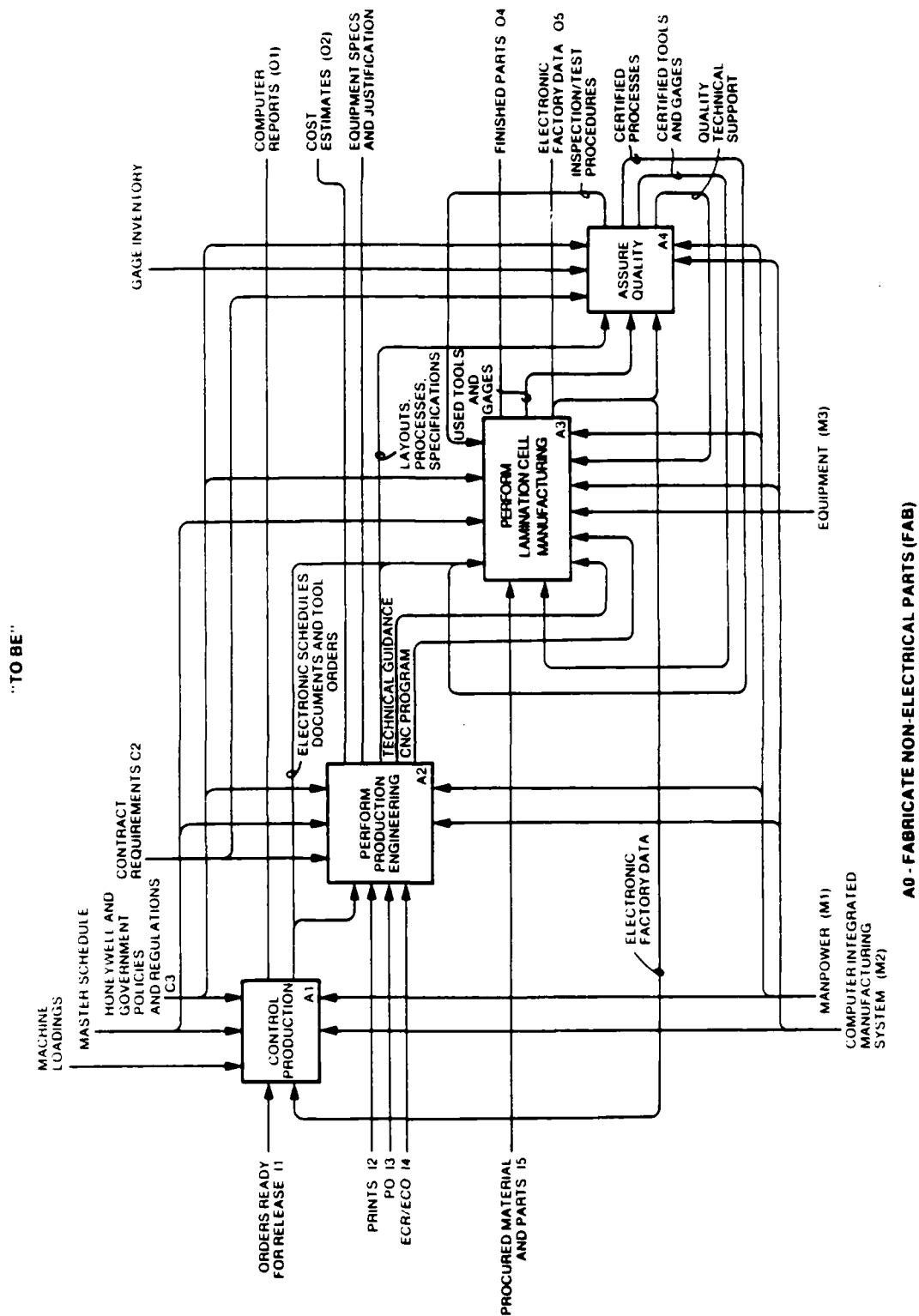
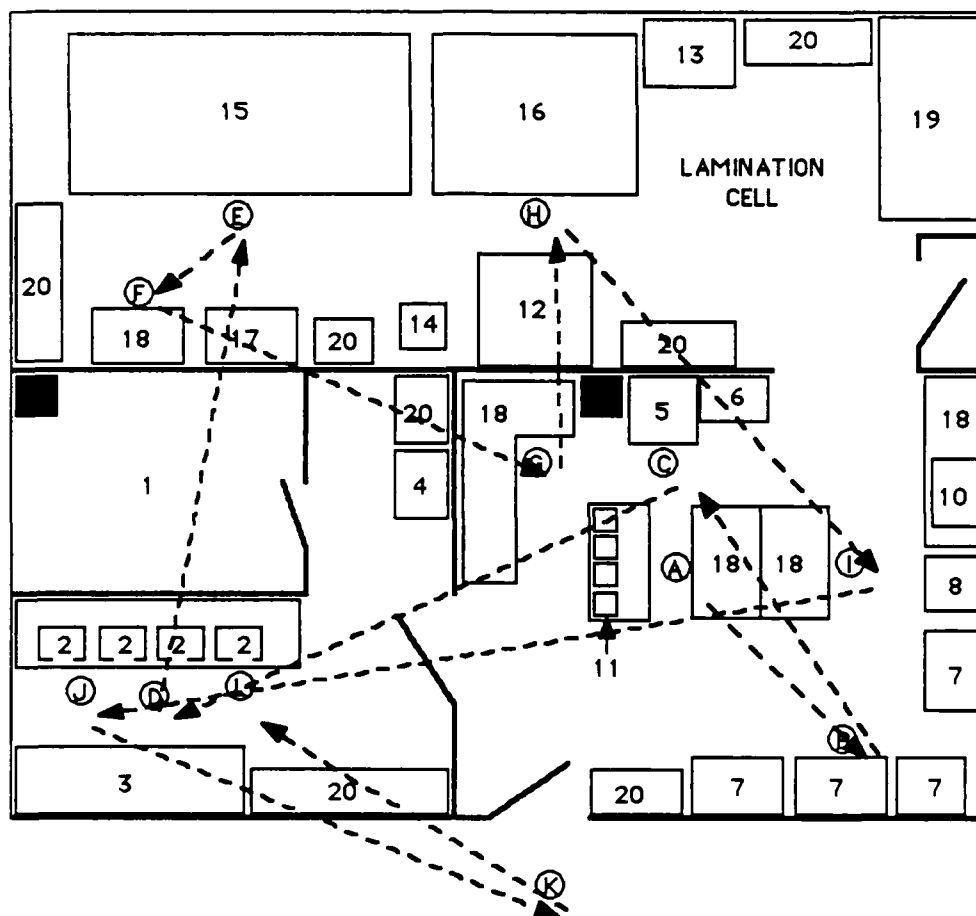


Figure 5.1 "To-Be" Lamination Workflow Diagram



#### SEQUENTIAL PROCESS FLOW

- A. Build Lamination Stacks
- B. Cure Cement
- C. Vacume Oven
- D. Soda Blast
- E. Internal Grind
- F. Deburr
- G. Assemble To Shaft
- H. Finish Grind
- I. Deburr
- J. Gritblast
- K. Bluecoat
- L. Soda Blast

#### DESCRIPTION OF EQUIPMENT

- 1. Soda Blast vacuum
- 2. SS White Soda Blast Units
- 3. Sink & Drain
- 4. Dry Ice Freezer
- 5. Dryer Oven
- 6. Bottled Gas
- 7. Ovens
- 8. Vented Hoods For Solvents
- 10. Burr Brushing Machine
- 11. Hot Presses
- 12. Lapping Machine
- 13. Ultra-sonic Cleaner
- 14. Center Lap
- 15. Internal Grinder (Bryant)
- 16. External Grinder (Tschudin)
- 17. Lapping Machine
- 18. Bench
- 19. Inspection
- 20. Shelving

Figure 5.2 "To-Be" Lamination Material Flow and Floor Layout



The Quality Assurance of the lamination stacks and assemblies will be handled by the operators in this work cell. Product Assurance will be responsible to train the operators and oversee all of the operations. Reference Project 43, Section 15.

The process flow of building a typical lamination assembly involves 14 steps (see Figure 5.3). These steps include:

- Count Laminations

The laminations will be counted and weighed by the operators to meet print requirements for the stack assembly. Operators will wear cotton finger cots when handling the individual laminations, so they do not damage the epoxy coating.

- Build Stacks

The individual laminations will be placed in fixtures and carefully pushed into the proper location. It is very important that the individual laminations are not mishandled during this operation, because the stack could be misaligned and the stack would be scrapped. The top of the fixture is assembled and this preloads the stack of laminations with a constant pressure, which is necessary while curing the epoxy.

- Cure Cement

The fixtures loaded properly with the individual lamination will be placed in racks in a preheated oven. The oven temperature and bake time will be monitored by the operators and recorded. This is critical because the proper temperature must be maintained for proper adhesion of the epoxy. The fixture will be unloaded from the oven and let to cool before being disassembled. Operators will take a sample of parts and check them for adhesion and voids as either condition causes problems in the final build area.

- Plasma Etch Vacuum Oven

The parts are placed on racks and placed in this oven. The operator selects the proper cycle for removing the excess cement from the exterior surfaces of the lamination stack. The oven has been programmed for the complete cycle. A vacuum is drawn, a chemical gas is allowed to enter the chamber, and an electronic field is used to break down the epoxy cement which is on the exterior surfaces. After this cycle, the operator removes the racks from the oven and unloads the racks.

- Abrasive Blast

The parts are then blasted to remove the light residue which is left on the lamination stacks. This is a quick operation as the vacuum oven has destroyed the surface adhesion of the epoxy. The operator will be using a dental blasting unit utilizing a light abrasive. The operator will check to make sure all of the epoxy is removed, as the bluecoating, which is applied later, will not flow properly if there is epoxy on the surface of the lamination stack.

**LAMINATION CELL  
PROCESS FLOW -- TO BE**

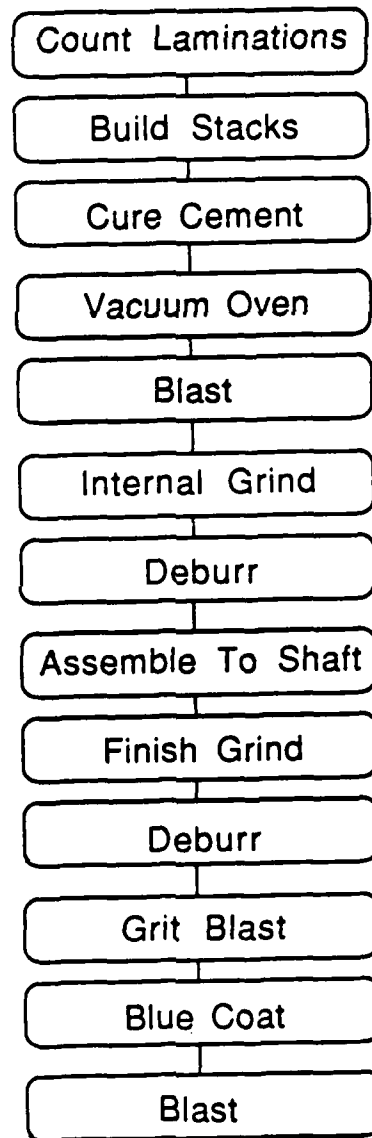


Figure 5.3 "To-Be" Lamination Process Flow

- Internal Grind

The lamination stack is placed in a fixture which is mounted and oriented on a CNC (Computer Numerical Control) internal grinder. The operator selects the pre-programmed cycle and the machine grinds the part. The operator checks the part for the correct size and unloads the fixture and reloads another part.

- Deburr

While the CNC internal grinder is grinding the next part, the operator has time to remove the grinding burrs. This saves moving parts around and places the responsibility on a single operator.

- Assemble to Shaft

The parts are moved within the work cell to have the shafts installed. The operator will orient the shaft in the stack to meet print requirements, place the assembly into a fixture located in an arbor press, and press the shaft into the proper location.

- Finish Grind

The assemblies are moved within the work cell to finish grind the external diameter on a CNC (Computer Numerical Control) external grinder. The operator loads each part on centers, and selects a pre-programmed cycle to machine grind the part. The machine cycle is programmed to incorporate the special grinding procedure, which is necessary, so the magnetics are not damaged. When the grinder stops, the operator unloads the part and loads a new part to be ground. Then the operator checks the part before deburring.

- Gritblast

The lamination assemblies are gritblasted for preparation for bluecoat, which is insulation, and necessary for the windings that PCI does in their final build area. The operator places masks over the critical surfaces that do not require gritblasting, and gritblast the remaining surfaces of the lamination assembly.

- Bluecoat

The lamination assemblies are moved out of the work cell into the blue coat area. Blue coat is an electrostatic coating which is used for insulating the winding, which are wound in PCI, from the lamination stack. The operator places special built masks to protect certain areas from bluecoat. Then the operator applies a thin film of bluecoat to the assembly and carefully places the parts in an oven to cure. After curing, the operator checks the bluecoat for voids or bubbles. The parts with voids or bubbles must be reworked.

- Abrasive Blast

The lamination assemblies move back into the blast area. Some areas of the lamination assemblies, which are bluecoated, have to be cleaned. Masks are placed on the assembly and the operator cleans these areas with blasting. After blasting, the operator cleans the parts and makes a final check to insure the lamination assembly meets all print requirements. The operator will input the inspection information into the inspection data collector. This procedure is covered in Tech Mod Project 43. Parts are then shipped to PCI for use in their final build.

## SECTION 6

### PROJECT ASSUMPTIONS

The project assumptions are detailed in Section 6 of the Project Overview. In addition, it is assumed that the Plasma Etch Oven will perform as tested on sample lots by the vendor.

## SECTION 7

### GROUP TECHNOLOGY CODING SYSTEM ANALYSIS

The "Lamination Cell" was formed as a result of the Group Technology techniques used to identify all the potential cells that could be formed. This approach is identified in Section 7 of the Project Overview.

## SECTION 8

### PRELIMINARY/FINAL DESIGN AND FINDINGS

Currently, the lamination stacks and assemblies are moved to many locations throughout the Fabrication Facility, as shown in Figure 8.1. This causes many delays in schedules and increases the quantity of parts that must be ordered to maintain inventory for the gyro final assembly.

A study of the manufacturing of the lamination stacks and assemblies was made by building a matrix of operations and machines that are currently used. Moving the existing machines and combining operations would result in less movement and loss time between operations. Another study was made to evaluate state of the art machines that would reduce part machining cost and set-up.

Next, the blasting process became the focal point. Blasting is necessary to remove the excessive epoxy from the exterior surfaces of the part, as discussed in Section 4. The first option evaluated was to use a robot to remove the epoxy from the lamination. Vendors in the field were contacted.

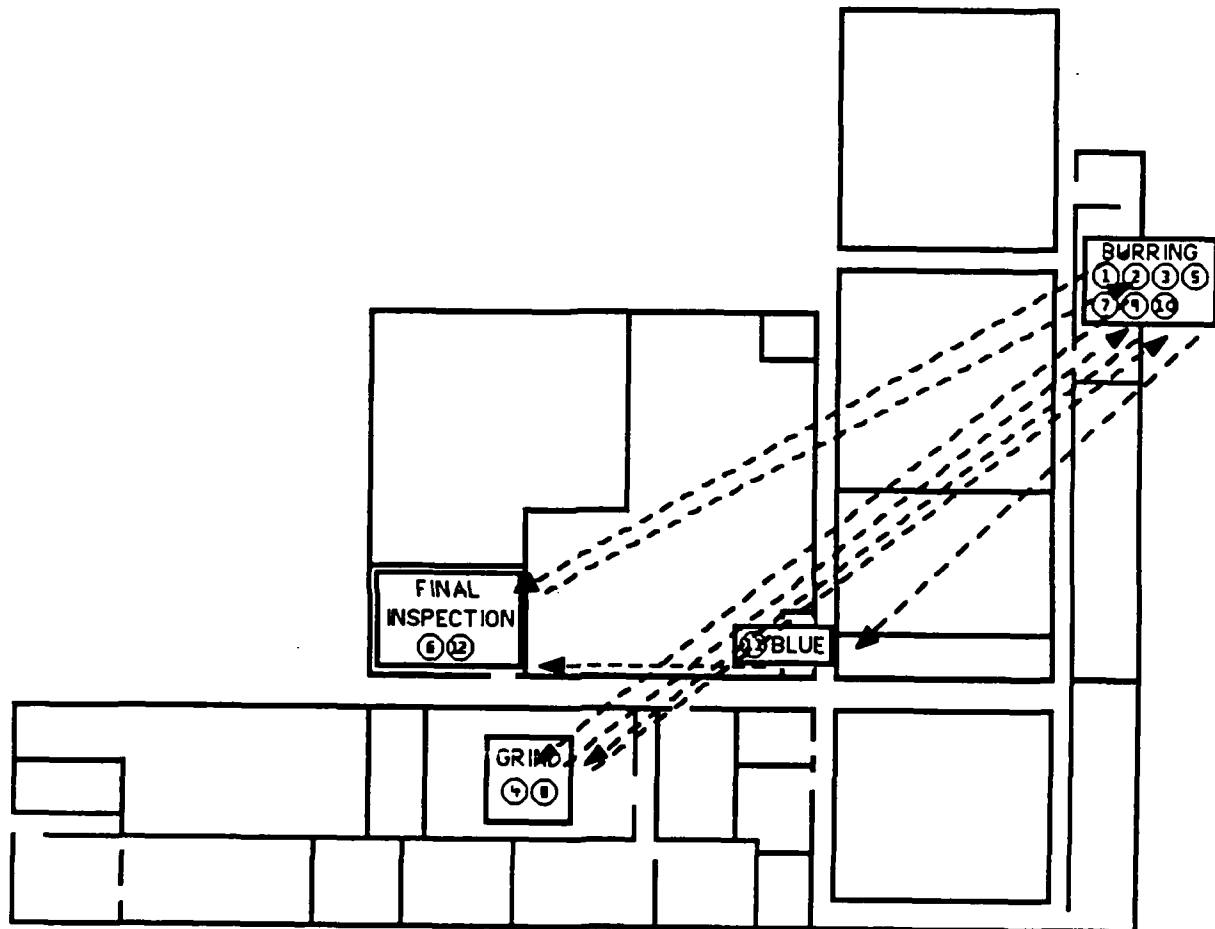
Each vendor proposed a concept and provided a quotation to perform the job. The initial cost was high, but the robot would be able to work continually until the quantity of parts for each order was finished. Very little set-up would be required for the next order of different lamination stacks. Careful handling of the parts would be necessary to prevent damage to the magnetic quality, but the vendors assured us that this could be accomplished by making special holding grippers.

Another vendor of lamination stacks proposed a new process which uses a vacuum oven, chemical gas, and electronics to eliminate epoxy coatings from the surface of their parts. The vacuum oven manufacture was contacted and sent ten part samples for evaluation. The results were excellent and a decision to use this type of equipment was made.

Grinding the lamination stacks and assemblies is another difficult and time consuming operation. Currently, manually operated grinders are used, and the machine operators are constantly making the necessary adjustments to grind parts to close tolerances. This eliminates the machine operators from doing any checking or deburring during the machining cycle. A study was made using computer numerical controlled (CNC) grinders. The results indicated reduced operator fatigue with increased performance and quality.

The study concluded with the design of a new Lamination Cell (see Figure 8.2). The design consolidates all of the assembling and manufacturing processes into one small area. This will greatly reduce the cost of the lamination assemblies.

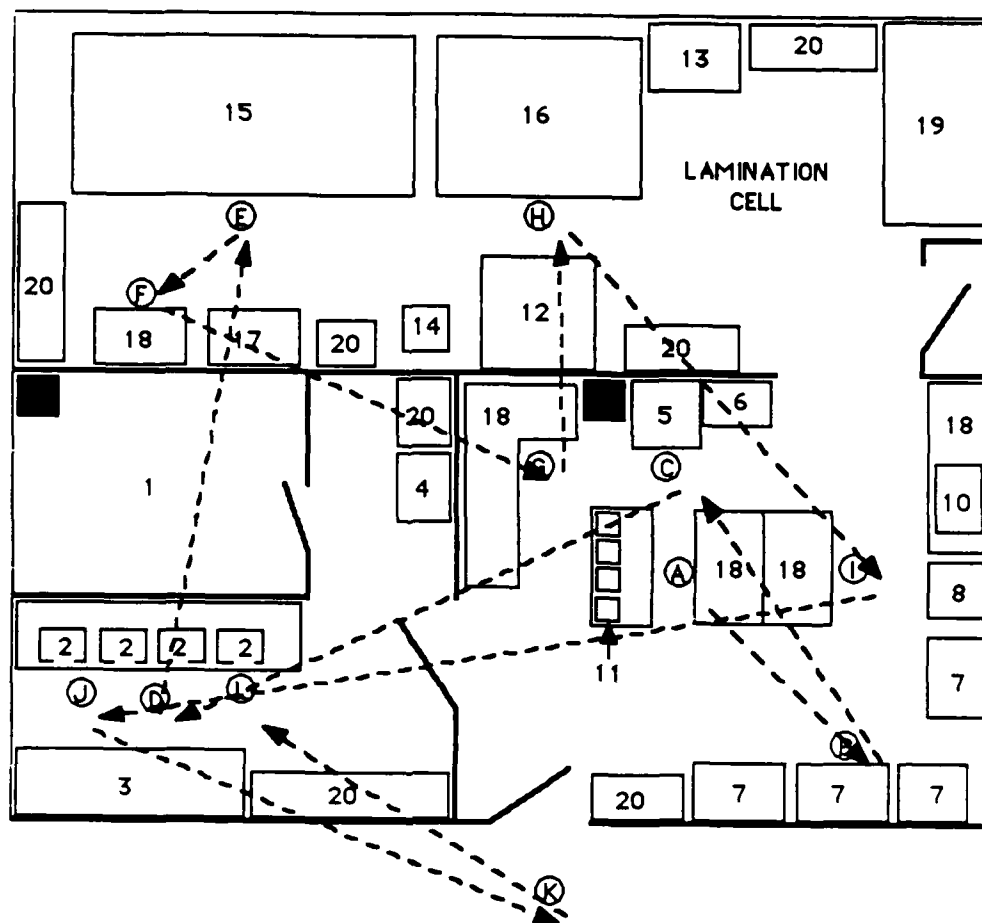
# **LAMINATION CELL MATERIAL FLOW -- AS IS**



- |                            |                      |
|----------------------------|----------------------|
| 1. Build Lamination Stacks | 7. Assemble To Shaft |
| 2. Cure Cement             | 8. Finish Grind      |
| 3. Soda Blast              | 9. Deburr            |
| 4. Internal Grind          | 10. Grit Blast       |
| 5. Deburr                  | 11. Bluecoat         |
| 6. Inspection              | 12. Final Inspection |

Figure 8.1 "As-Is" Lamination Material Flow





#### SEQUENTIAL PROCESS FLOW

- A. Build Lamination Stacks
- B. Cure Cement
- C. Vacume Oven
- D. Soda Blast
- E. Internal Grind
- F. Deburr
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- 16. External Grinder (Tschudin)
- 17. Lapping Machine
- 18. Bench
- 19. Inspection
- 20. Shelving

Figure 8.2 "To-Be" Lamination Material Flow and Floor Layout

## SECTION 9

### SYSTEM/EQUIPMENT/MACHINING SPECIFICATIONS

The following specification must be met by the vendor for an epoxy removal system. The conditions are:

- Reduce the excessive cement on exterior surface of parts.
- Do not damage cement between laminations.
- Do not corrode the surfaces.
- Do not damage the magnetics of laminations.
- The oven chamber must have minimum dimensions of 24 inches wide, 14 inches deep, and 13 inches high.
- Utilize automatic controllers to operate oven.
- The system must meet all safety standards.
- The floor space including all components is 4 X 8 feet.

The following specifications must be met by the vendor for an outside diameter computer numerical control (CNC) grinding machine.

- Distance between centers - 28 inches.
- Swing - 8 inches.
- Traverse Movement - 24 inches.
- Traverse Speed - 19 to 196 inches/minute.
- Swiveling Range -  $\pm 8$  degrees.
- Wheel Diameter - 20 inches.
- Minimum Infeed Increments - .000020 inches.
- Variable Spindle Speed - 65 to 500 RPM.
- CNC Controller:
  - Control Grinding Cycle.
  - Dress Wheel to desired contour.
- Approximate floor space - 10 X 10 feet.

The following specifications must be met by the vendor for an inside diameter computer numerical control (CNC) grinder.

- Maximum Diameter - 6 inches.
- Maximum Length of Bore - 2 inches.
- Minimum diameter of Bore - .040 inches.
- Longitudinal Table Travel - 8 inches.
- Cross slide Table Travel - 4 inches.
- Feed Rates - 0 to 600 inches/minute.
- CNC Controlled Work Head
  - Angled Settings - 5 to 45 degrees.
  - Resolutions - 4 arc seconds.
- Wheel Speed - to 150,000 RPM.
- Work Head - 180 to 3600 RPM.
- Occupy less than 10 X 15 feet of floor space.

## SECTION 10

### TOOLING SPECIFICATIONS

The following specifications must be met by a vendor or internal Honeywell department to bid.

#### EPOXY REMOVAL OVEN

- Standard racks to hold parts while in oven.
- No other tools are necessary.

#### EXTERNAL GRINDER

- Use existing fixtures; modify mounting, if required, to fit specific vendor machine.
- Standard grinding wheels as supplied by vendor.
- Develop computer numerical control programs to control the grinding operation. These files will be generated for each operation after the machines are delivered. They will be developed and debugged by engineers during machine acceptance and factory training.

#### INTERNAL GRINDER

- Use existing fixtures, modify if required, to fit specific vendor machine.
- Standard grinding wheels as supplied by vendor.
- Standard diamond dresser as supplied by vendor.
- Develop computer numerical control files to control the grinding operation. These NC programs will be generated for each operation after the machines are delivered. The complete operation will be developed and debugged by engineers during machine acceptance and operator training.

## SECTION 11

### VENDOR/INDUSTRY ANALYSIS/FINDINGS

An industry survey was conducted to identify the companies that are capable of supplying the following items to meet the requirements of the Lamination Cell:

- Cylindrical Grinder
- CNC - Internal Grinder
- Plasma Etching

#### SELECTION CRITERIA

An industry search was conducted to identify the companies that would be capable equipment suppliers/integrators. In view of the many on going advances in machine tool automation and metal removal technology, we tend to think of modern mechanical manufacturing (CNC "Computer Numerical Control") as a highly productive and efficient process. The information for preparing this evaluation was obtained by:

- Conducting an extensive literature search (local and foreign), Thomas Register, technical journals, advertisements, etc.
- Contacting suppliers.
- Visiting a few companies.

In order to obtain detailed information, part drawings and, in some cases, sample parts were prepared and sent to selected companies to obtain first hand information and time estimates.

After review and assessment of the companies active in the market, several vendors were selected based on the following criteria (not listed by priority or importance):

- Capability to deliver.
- Servicing and training support.
- Machine requirements and capabilities.
- Project support in supplying pertinent data.
- Size and financial stability as indicated by Dunn & Bradstreet reports.

Although tool cost, which reflects both the price of the equipment and its durability, is important, it is not necessarily the ultimate criteria. The ultimate criteria, depending on objectives, is either minimum total cost of the machining operation or maximum production rate.

The vendors were supplied with part prints and generic equipment requirements. They were required to give time estimates, detail equipment specifications and current price quotes on the parts that were supplied to them. The following are a list of companies (by equipment category) contacted during the survey:

#### CNC - External Grinding

- Concept Machine - Litton Ind. (Landis)
- Productivity Inc. - Tschudin Grinding Corp.
- Stone Machinery - Studer A.G.
- Milton Granquist Comp. - Sheffield Mach.
- Hegmam Mach. Tool - Toyoda Works, Ltd.

#### CNC - Internal Grinding

- Bryant Grinder Corp.
- Concept Mach. - Landis Tool
- John C. Eider Co. - Voumard Mach. Co.
- Satterlee Co. - Okamoto Works, Ltd.
- Anderson Mach. - Danobat

#### Plasma Etching

- Material Research Lab N.J.
- Balzer, New Hampshire
- Dry-Tek Inc., Wilmington MA.

#### SELECTION CRITERIA

The selection criteria for potential equipment suppliers consisted of several levels of response and evaluation. They were also directed to be completely responsive to the specification, itemizing exceptions or alternatives proposed. It was asked that these vendors give time estimates on production parts, equipment and required accessories and costs for evaluation.

As a result, the following equipment and vendors were chosen:

- Stone Machinery Co. - Studer Model S20-2

This machine was selected for its state of the art technology. The equipment incorporates some of the most advanced engineering features. It utilizes modern techniques combined with ease of operation to solve simple grinding jobs. The equipment is a totally automatic production machine. It features the ability to grind multiple diameters with maximum precision and at high production rates.

- Bryant Grinder Corp. - Model LL2-CNC

This machine was selected for its state-of-the-art technology in design, construction, precision and control. Constructed with standardized, modular components and computerized numerical controls, it demonstrates greater versatility and ease of operation at a price comparable to conventional grinding.

- Drytek-Mega Strip-6

With a limited number of vendors supplying this type of system, it was difficult to receive responses from the vendors. The only supplier at this time, willing to provide us with a system quote was Drytek. Sample parts were sent to Drytek for systems approval. The results were satisfactory and met all expectations requested by this investigation.

## SECTION 12

### EQUIPMENT/MACHINERY ALTERNATIVES

If for any reason the preferred equipment will not be available (long lead time, capability to deliver, excessive equipment cost increase, etc.) a similar machine of the same capabilities, but not necessarily of the same manufacture will be procured. This may include:

- Landis IR CNC Cylindrical Grinder

This machine was selected as an alternative because of its high performance and accuracy. The control system features a fully-integrated programmable controller, menu programming and permanently active diagnostics. The equipment performance is comparable to the Studer Model S20-2 in all aspects.

- Landis-UVA Internal Grinder

This machine was selected as an alternative for the same reason as item #1. The equipment performance is very comparable to the Bryant Grinder Model LL2-CNC.

- Plasma Etching

Three vendors were contacted as shown in Section 11. Two of the vendors refused to bid because the parts were too small for their equipment and they were not familiar with this type of plasma etching.



## SECTION 13

### MIS REQUIREMENTS/IMPROVEMENTS

All systems in this proposed Lamination Cell will interface as outlined in Section 13 of the Project Overview.

## SECTION 14

### COST BENEFIT ANALYSIS/PROCEDURES

#### OVERVIEW

The Lamination Cell is a dedicated cell that will process a majority of Honeywell's laminated assemblies. These assemblies are primarily used on our inertial component devices, such as GG1111, GNATS, and GG4400 (i.e., Iron Gyros). The project team has analyzed a total of eleven individual part numbers for this cell, which were used for the calculation of cell savings. The cost drivers for this cell were identified using the methodology shown in the process diagram of Figure 14.1.

#### MANUFACTURING SCHEDULE

The manufacturing schedule for this cell used the marketing plan volume projections by product device. Attrition and part usage per device were accumulated to develop the ten year projections.

#### ACTUAL STANDARD HOUR SAVINGS

The methodology for deriving the "As-Is" and "To-Be" actual standard hours was followed as described in Section 14 of the Project Overview.

#### CAPITAL AND EXPENSE

The capital, recurring and non-recurring expense for the Lamination Cell are shown in Figure 14.2.

#### PROJECT SAVINGS AND CASH FLOWS

The savings to be realized by this cell exceed Honeywell's Military Avionics Division hurdle rate. The cell's cash flows are shown in Figure 14.3 with the assumption that capital is available per the implementation plan.

## COST BENEFIT ANALYSIS METHODOLOGY

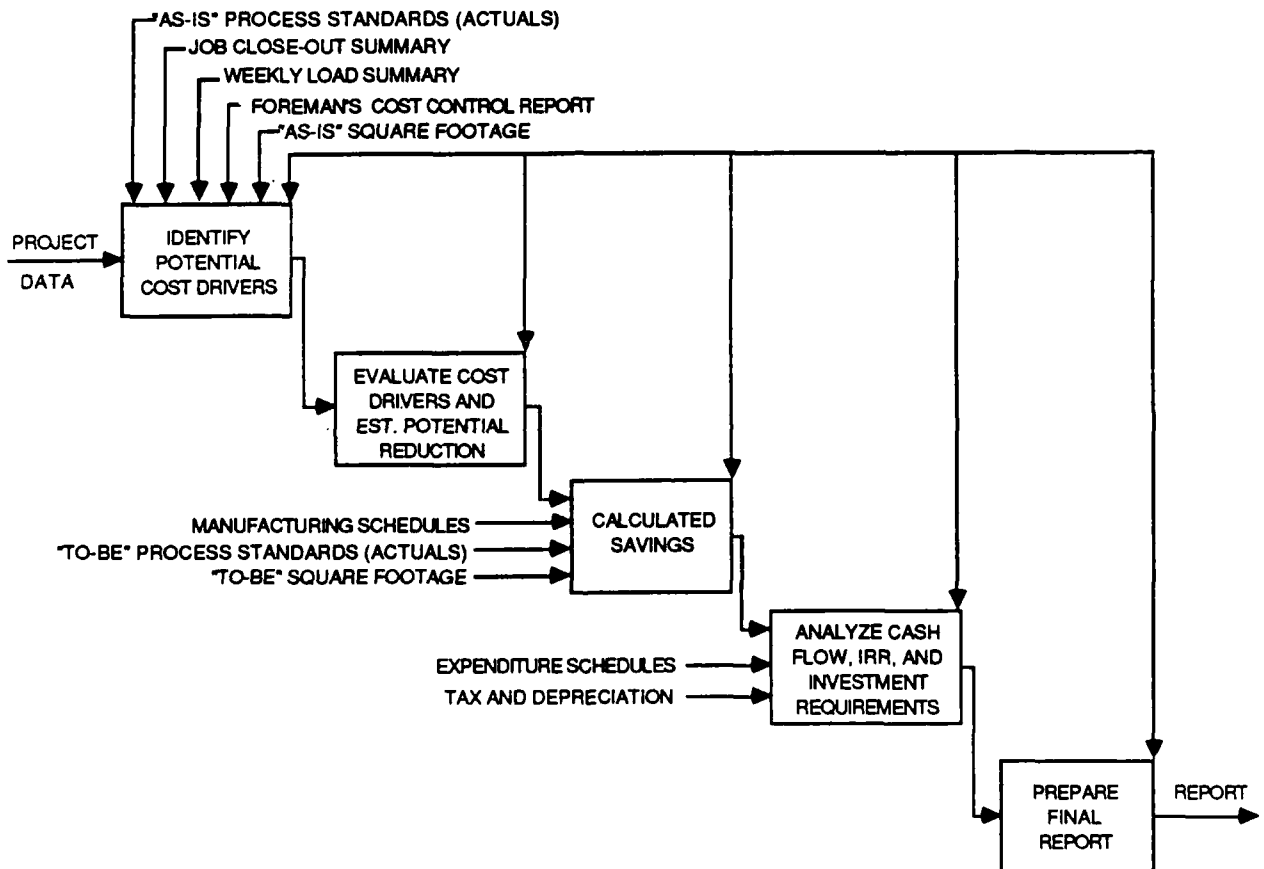


Figure 14.1 Lamination Cell Cost Benefit Analysis Methodology

**LAMINATION CELL  
EXPENDITURE SCHEDULE**

	Cost	Capitalization Date
<b>CAPITAL COSTS</b>		
<b>MACHINERY COSTS</b>		
** CNC Grinder External	\$80,385	1989
** CNC Grinder Internal	\$320,200	1989
** Vacuum Oven	\$66,988	1989
** Area Preparation (Material)	\$4,019	1989
** Tooling (HI)	\$5,750	1989
** Tooling (Purchased)	\$2,680	1989
	-----	
TOTAL MACHINERY COSTS	\$480,022	
<b>FURNITURE COSTS</b>		
** Storage Cabinet	\$670	1989
	-----	
TOTAL FURNITURE COSTS	\$670	
	-----	
TOTAL CAPITAL COSTS	\$480,691	1989
<b>EXPENSE COSTS</b>		
<b>NON-RECURRING EXPENSES</b>		
Area Preparation Labor (HI)	\$32,400	1989
Training (HI)	\$1,000	1989
Process Development Direct Labor	\$4,000	1989
Post Processor Development Direct Labor	\$500	1989
	-----	
TOTAL NON-RECURRING COSTS	\$37,900	1989
	-----	
TOTAL CAPITAL + NON-RECURRING	\$518,591	1989
<b>RECURRING EXPENSES</b>		
• Annual Maintenance (Mechanical)	\$500	
• Annual Maintenance ( Computer HW)	\$233	
• Annual Maintenance (Computer SW)	\$233	
	-----	
TOTAL RECURRING	\$966	
• Expense starts in year 2.		
** Costs contain a 15% contingency		

Figure 14.2 Lamination Cell Expenditure Schedule

TECH MOD PHASE 2

PROJECT 44 -- LAMINATION CELL

PROJECT CASH FLOW SUMMARY  
(\$000)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	TOTAL
Capital	\$480.7	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$480.7
Non-Recurring Expenses	\$37.9	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$37.9
Recurring Expenses	\$0.0	\$0.0	\$1.0	\$1.0	\$1.0	\$1.0	\$1.0	\$1.0	\$1.0	\$1.0	\$1.0	\$8.7
Total Savings	\$0.0	\$160.4	\$159.7	\$164.1	\$172.0	\$180.4	\$189.2	\$198.1	\$207.2	\$216.3	\$225.4	\$1,872.8
Depreciation	\$48.0	\$86.5	\$69.2	\$55.4	\$44.3	\$35.4	\$28.4	\$32.4	\$32.4	\$32.4	\$16.3	\$480.7

Figure 14.3 Lamination Cell Cash Flows

## SECTION 15

### IMPLEMENTATION PLAN

Start of the Implementation Plan for the Lamination Cell will begin in the last Quarter of 1988, as shown in Figure 15.1.

Last Quarter of 1988:

- Purchase order released.

First Quarter of 1989:

- Start designing special tooling

Second through Fourth Quarters of 1989:

- Approve tool drawings.
- Build tools.
- Install power lines.
- Install air and vents.
- Rearrange current equipment.
- Receive new equipment.
- Train personnel.
- Try out tooling.
- Install and debug equipment.
- Phase into pilot production.

# LAMINATION CELL IMPLEMENTATION SCHEDULE

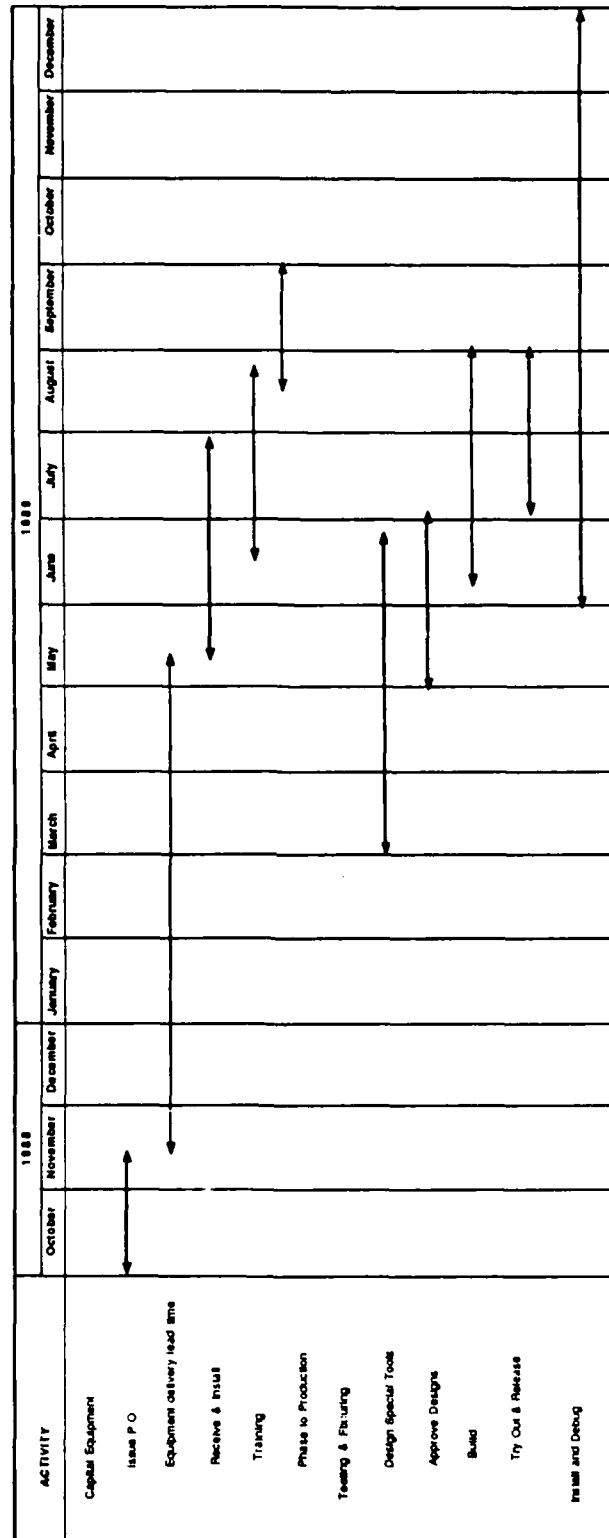


Figure 15.1 Lamination Cell Implementation Plan

## SECTION 16

### PROBLEMS ENCOUNTERED AND HOW RESOLVED

Problems and solutions of general concern are detailed in Section 16 of the Project Overview. In addition, the specific problems encountered were:

Problem: The first sample of Lamination stack that was sent to the vendor for epoxy removal, under normal process was badly corroded.

Solution: The vendor changed the gas flow and mixture to eliminate this corrosion problem. The results were excellent.



## SECTION 17

### AREAS FOR FUTURE CONCERNS/DEVELOPMENT

Future concerns and developments in general are detailed in Section 17 of the Project Overview.

#### FUTURE DEVELOPMENT

A wire electric discharge machine (EDM) should be considered for new low volume and experimental lamination assemblies. Using EDM technology would eliminate expensive permanent tooling costs for development and low volume lamination stacks. When a firm design is made and schedules show a need for high volume, permanent tooling would be built to reduce the cost of the lamination stacks.

## PROJECT 44

### GIRTH RING CELL

#### SECTION 1

#### INTRODUCTION

The housing and balance pan assembly is a laser welded and machined assembly consisting of a girth ring, a motor housing and balance pan sub-assembly. A detailed sketch of the major components (*Girth Ring and Motor Housing*) of this cell are shown in Figure 1.1. It is one of the major components of the GG1111 series gyro's. These parts are, approximately 1 1/8 inch in diameter by 1 inch long, cast aluminum housings. They are machined to tolerances of  $\pm 0.001$  on the diameter. The operations that are performed to manufacture the motor housing, with all its components, allow themselves to be grouped and isolated in a manufacturing cell. The proposed cell integrates corresponding PCI (Precision Control Instruments) assembly and Fab Fac (Fabrication Facility) machining operations into one segregated work area. This section of Project 44 describes the step-by-step details of the formation of the "Girth Ring Cell".

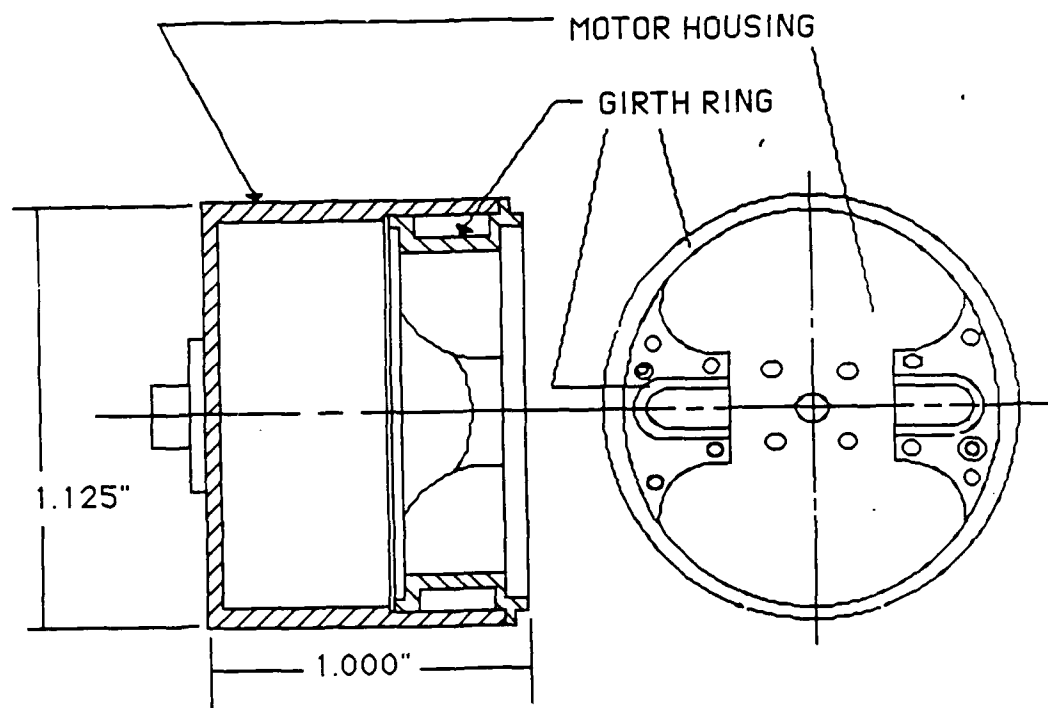


Figure 1.1 Housing and Girth Ring Illustration

## SECTION 2

### PROJECT PURPOSE/OVERVIEW

The objective of the "To-Be" approach for the "Girth Ring Cell" is to increase the productivity and decrease the throughput time for one of the major components of the GG1111 series Gyro's.

The "As-Is" processes for these components were gathered and thoroughly analyzed. The sequence of some operations were rearranged and process method changes were introduced that resulted in a reduction of cost. This methodology established a basis for the "To-Be" process.

With this cellular manufacturing approach, the following benefits were achieved: reduction in cost, reduced lead time, reduced Work-In-Process (WIP) inventory, more efficient material handling, reduced material control, and flexibility to meet customer demands.

## SECTION 3

### TECHNICAL APPROACH

The GG1111 Gyro motor and housing assembly contains six components, produced in the Fabrication Facility and Precision Control Instruments assembly work areas, that were analyzed and found suitable for a dedicated work cell/center configuration. These components have redundant operations that can be reduced by grouping them into one segregated work area to form a work cell.

The "Girth Ring Cell" studies led to the following approach in identifying the structure for this manufacturing cell.

1. The overall analysis for this cell follows the procedure described in Section 3 of the Project Overview.
2. With the data compiled through the part matrix, six components were selected as excellent candidates for a cellular approach because they had common operations with similar equipment requirements.
3. Part prints for these components were matched with corresponding routings and the parts were analyzed for methods and process improvements.
4. Forecasted quantities and labor studies were used to simulate cell loading.
5. A thorough equipment and technology search was conducted to determine the best selection of equipment for this cell.
6. A preliminary design was selected based on process commonalties, simulations, layout, equipment and technology searches.
7. A cost benefit analysis was prepared showing projected savings, expenses, IRR, etc.
8. An implementation plan was developed defining installation, rearrangement, and interface with operating systems.

## SECTION 4

### "AS-IS" PROCESS

The present method of machining the six designated components dedicated to the "Girth Ring Cell" within Honeywell's Military Avionics Divisions Fabrication Facility (Fab Fac) follow the traditional philosophy of a single disciplined department, performing only one machining operation. This discipline strongly highlights the short comings and inefficiencies in the present "As-Is" operation. Complicated material flow, excessive lead times, excessive rework, scrap and salvage create an undesirable and added cost to the product. The "As-Is" process for the Fab Facility is shown in Figure 4.1. These inefficiencies are highlighted below:

#### MATERIAL FLOW AND MATERIAL HANDLING

The components identified for this cell follow a complex flow through the shop. They are fabricated partially by one department and moved between the departments according to layouts or process sheet instructions. With no centralization of these work areas, parts are often moved from one end of the building to the other with long delays, large staging areas and long delivery schedules. This situation creates undesirable material flow conditions which causes difficulties in material control. Figure 4.2 demonstrates the present material flow in the shop for the parts involved in the "Girth Ring Cell".

#### PROCESS REQUIREMENTS

The parts involved, under present conditions, follow complicated process requirements. They follow a single disciplined, batch operation philosophy. All styles of parts, with different characteristics are run with this traditional approach. With these types of requirements, the material follows a random movement through the manufacturing area. The sequential process flow diagram shown in Figure 4.3 identifies the "As-Is" manufacturing operations required to build the components selected for this cell.

#### FACILITY LAYOUT

The components in the Girth Ring Cell are presently produced in four scattered areas throughout the building. This inefficient layout causes undesirable material flow conditions, which create large staging area's, long delays and delayed delivery schedules. Figure 4.2 indicates the complex "As-Is" process/material flow of the components involved in the "Girth Ring" cell.

#### PRODUCTION CONTROL/SCHEDULING

With the current Production Control process, manual schedules are released to control production on the floor. Manual device schedules are updated by production control personnel and status is communicated back to the product line.

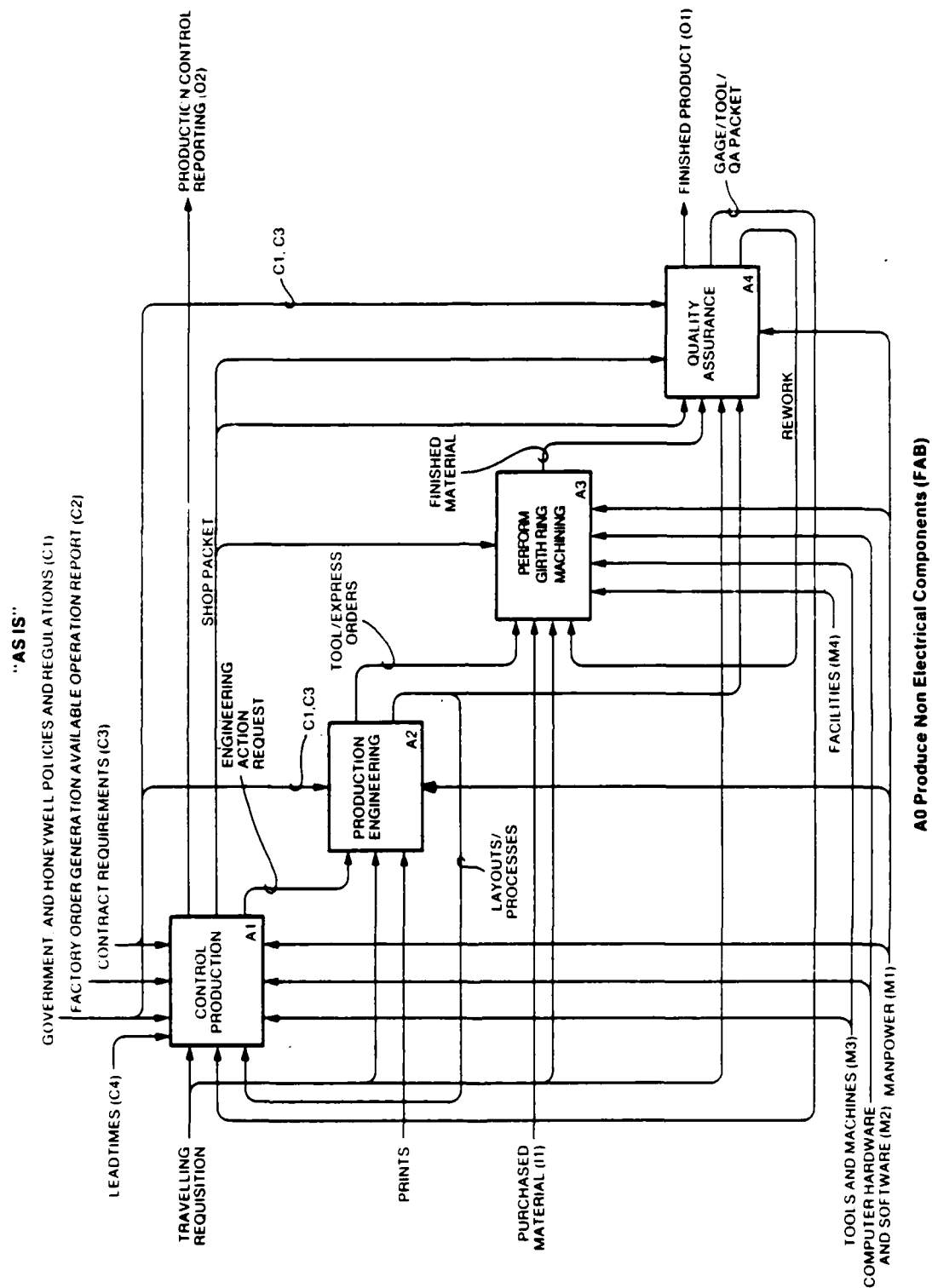
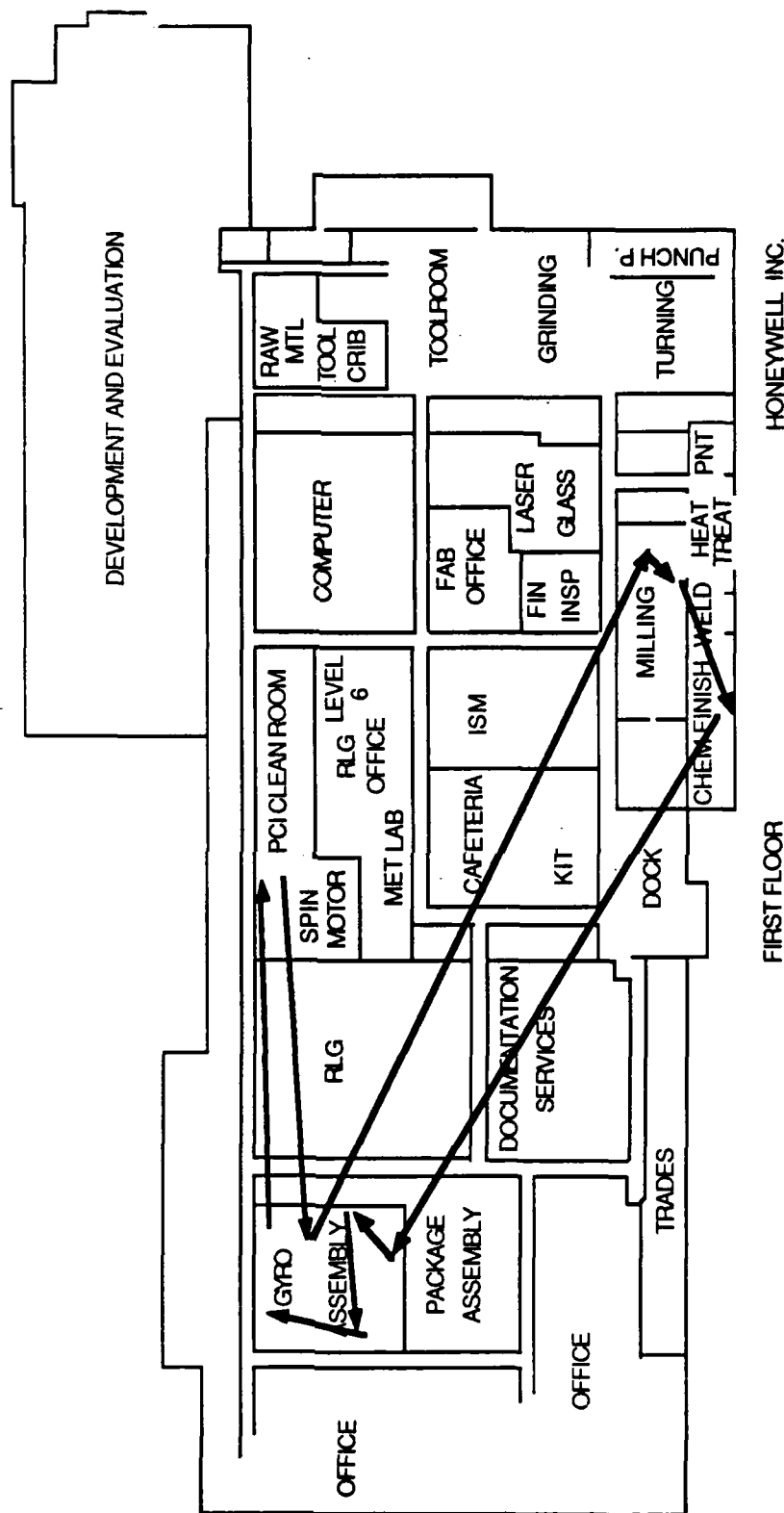


Figure 4.1 "As-Is" Housing/Girth Ring Workflow Diagram

# GIRTH RING CELL MATERIAL FLOW -- AS IS



HONEYWELL INC.  
Military Avionics Division  
Stinson/Ridgway

FIRST FLOOR

Figure 4.2 "As-Is" Housing/Girth Ring Layout and Material Flow



## HSG. & GIRTH ASSY



## QUALITY CONTROL

As parts are machined, they are routed from machine to machine until the inspection operation is reached. The parts are then brought into the inspection staging area to be assigned a priority for inspection. After completion of inspection, parts are routed through the subsequent operations until another inspection operation is reached. If the parts are rejected at an inspection operation, and must be reworked, they are routed back to the manufacturing group for rework causing additional delays due to lack of scheduling.

## EQUIPMENT

The equipment utilized in producing the "Girth Ring" cell components are located in the four areas throughout the Fab Fac and Precision Control Instruments (PCI) areas. The equipment required to perform the machining operations located in the Fab Fac area include a turning machine, milling center, grit blast booth and a cleaning tank. PCI's equipment involves a welding operation done in a laser welder. The gauging and inspection done on the parts is accomplished through standard gauges such as plug and ring gauges, height gauges, verniers, micrometers and thread gauges. None of this equipment will automatically record acceptance data.

## SECTION 5

### "TO-BE" PROCESS

#### INTRODUCTION

The proposed "Girth Ring Cell" consists of six parts that undergo common operations and use common equipment. The cell is dedicated to the production of this part group. In this approach, the following issues are the main drivers.

- Work flow
- Lead times
- Material flow/material control
- Process requirements
- Work-In-Process inventory
- Facility layout
- Quality Control

#### WORK FLOW

The machining of the six gyro components are dedicated to this "Girth Ring" cell. This cell is setup to support the GG1111 product line. It contains equipment to perform operations including milling, turning, laser weld, clean, grit blast and impregnation. These tasks have evenly balanced cycle times. With this approach, an even work flow is achieved. How this work is scheduled through the cell is represented in Figure 5.1.

#### LEAD TIMES

With this cell approach, lead times can drastically be reduced from the longest item being 152 days to a potential delivery in 5 days of any component dedicated to the cell. This improved condition was mainly due to the improvements in the process and layout configuration.

#### MATERIAL FLOW/MATERIAL CONTROL

The formation of the "Girth Ring Cell" and the new process simplified the material flow and reduced the total travel distance to within the cell area. Material control is achieved through an on-line, MRP II integrated manufacturing system (Honeywell Manufacturing System). Through this system, processes, schedules, material requirements, detailed operator instructions, machine programs and order status are available on-line. With these features, a continuous process flow can be achieved with positive material flow and control. As shown in Figure 5.2., material will enter into the cell at sequence one and follow the remaining sequential steps through the process until completed. The parts at this stage will not be returned for any further work. They will be supplied to PCI's paced assembly line (ITM Project 51/52).

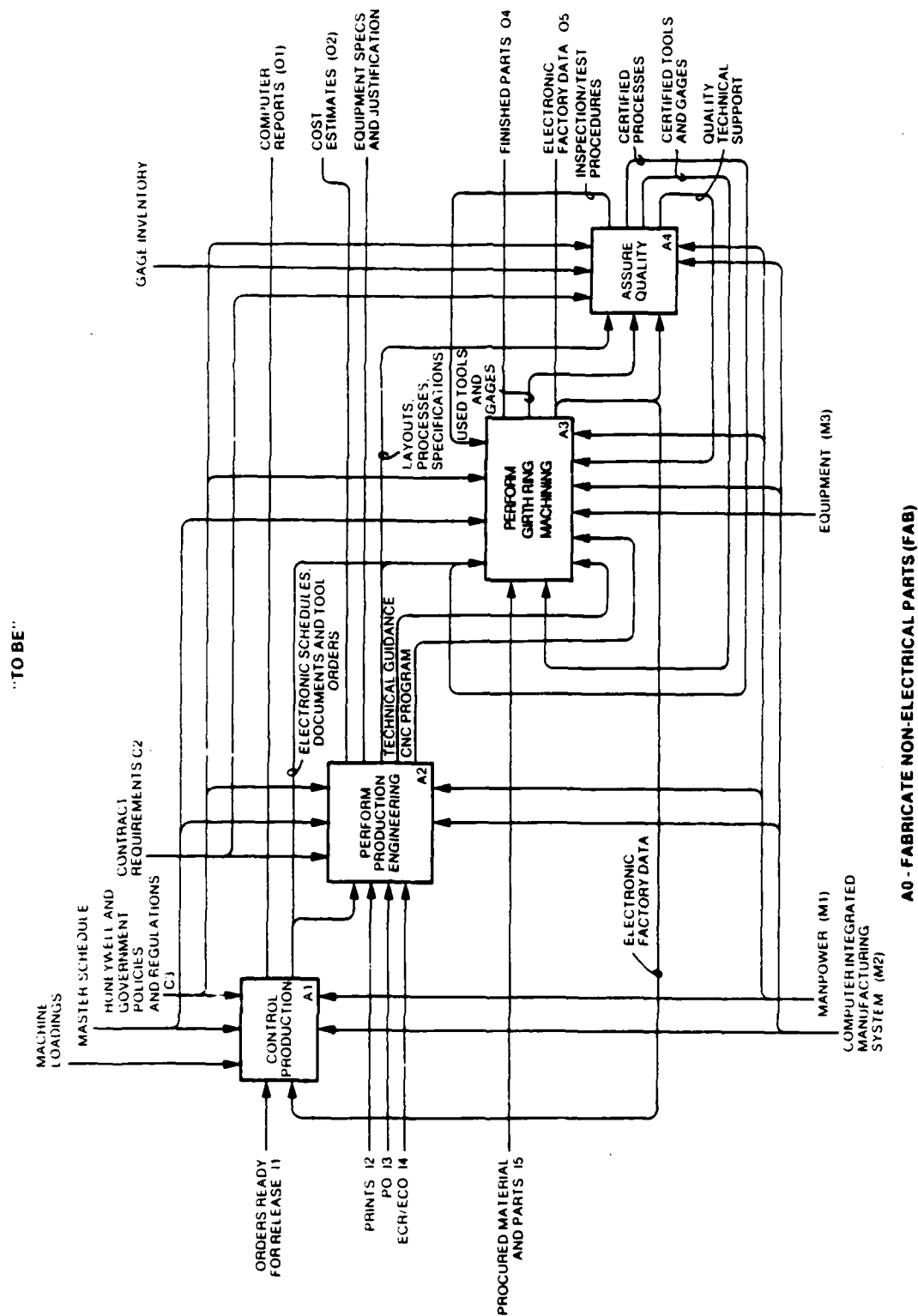


Figure 5.1 "To-Be" Housing/Girth Ring Workflow Diagram

# **GIRTH RING CELL LAYOUT AND MATERIAL FLOW TO BE**

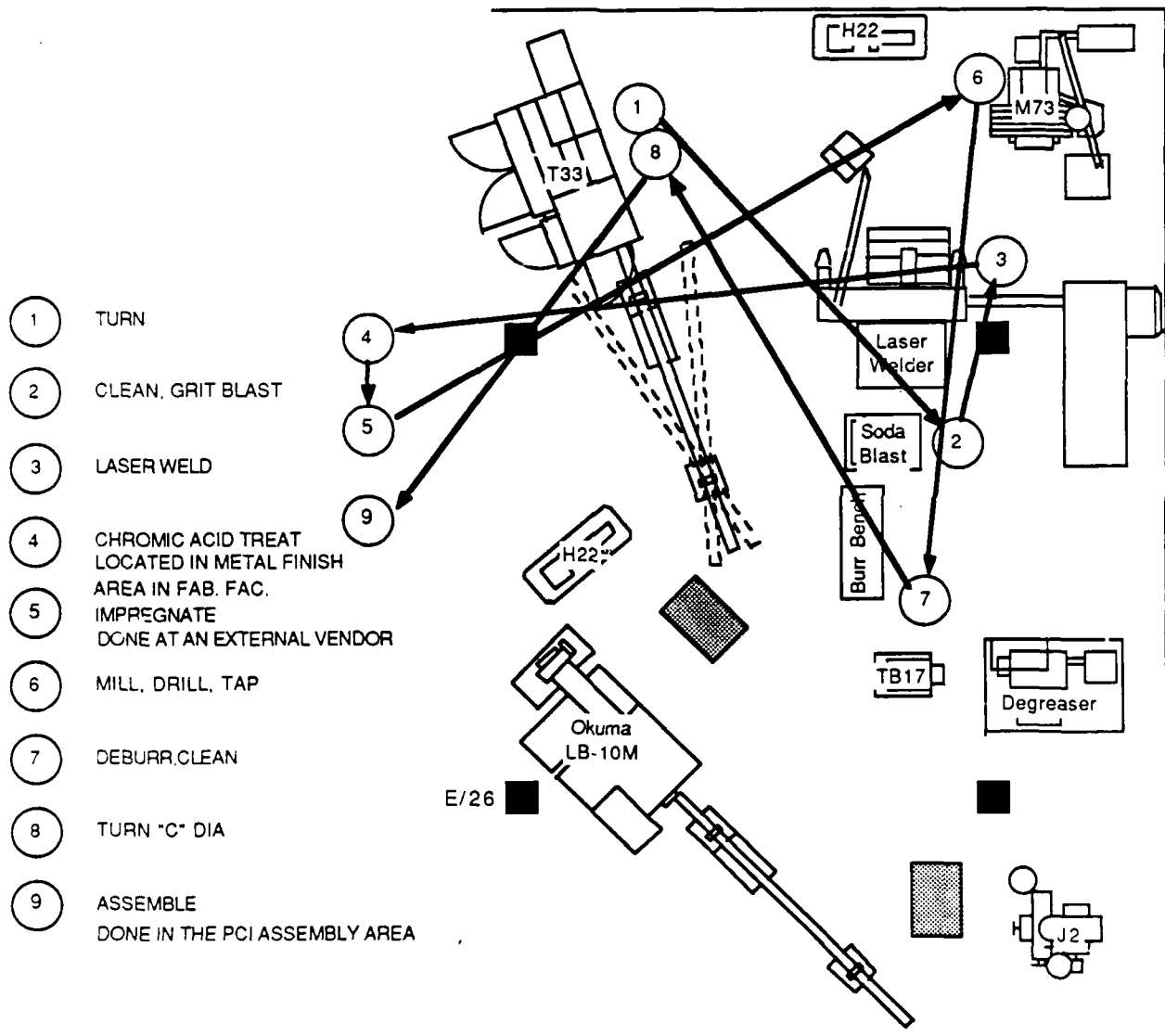


Figure 5.2 "To-Be" Housing/Girth Ring Cell Layout and Material Flow

## PROCESS REQUIREMENTS

The "Girth Ring" cell concept applies to a moderate volume, dedicated, production environment. It integrates a group of flexible general purpose machines and tools into a cell that manufactures parts with process commonalities. These commonalities are identified in the sequential process flow diagram shown in Figure 5.3.

## WORK IN PROCESS INVENTORY

Dependant on the yearly quantities, the "To-Be" approach will reduce the Work-In-Process (WIP) inventories. At no time shall there be more than a two week production quantity in-process. Procedures for the production control functions will be upgraded to meet the requirements of this improved manufacturing cell. With a balanced and paced manufacturing cell, lead times and WIP will be reduced. The cell will be monitored through a Factory Data Collection (FDC) system. Order status will be available to the user's of the system. With these controls, order sizes, lot size and buffer loads can be monitored and controlled.

## FACILITY LAYOUT

The "To-Be" layout shown in Figure 5.2 is the result of the rearrangement. This was accomplished by analyzing the manufacturing flow paths for each component in the cell. The flow paths are equipped with an adequate amount of equipment to satisfy the requirements of the parts. The formation of the "Girth Ring" cell localizes the manufacturing operations into a single cell achieving a substantial savings in floor space.

## QUALITY CONTROL

The production operator will gauge and check his work with variable instruments. The gauges will be digital display with electronic output going to a data collector. A predetermined lot size will be identified for inspection, which the operator will check during the cycle time. This is described in further depth in Project 43, Section 5. The benefits derived from this are improved quality, reduced throughput time, reduced scrap/rework and reduced inspection cost.

# **GIRTH RING CELL PROCESS AND FLOW DIAGRAM -- TO BE**

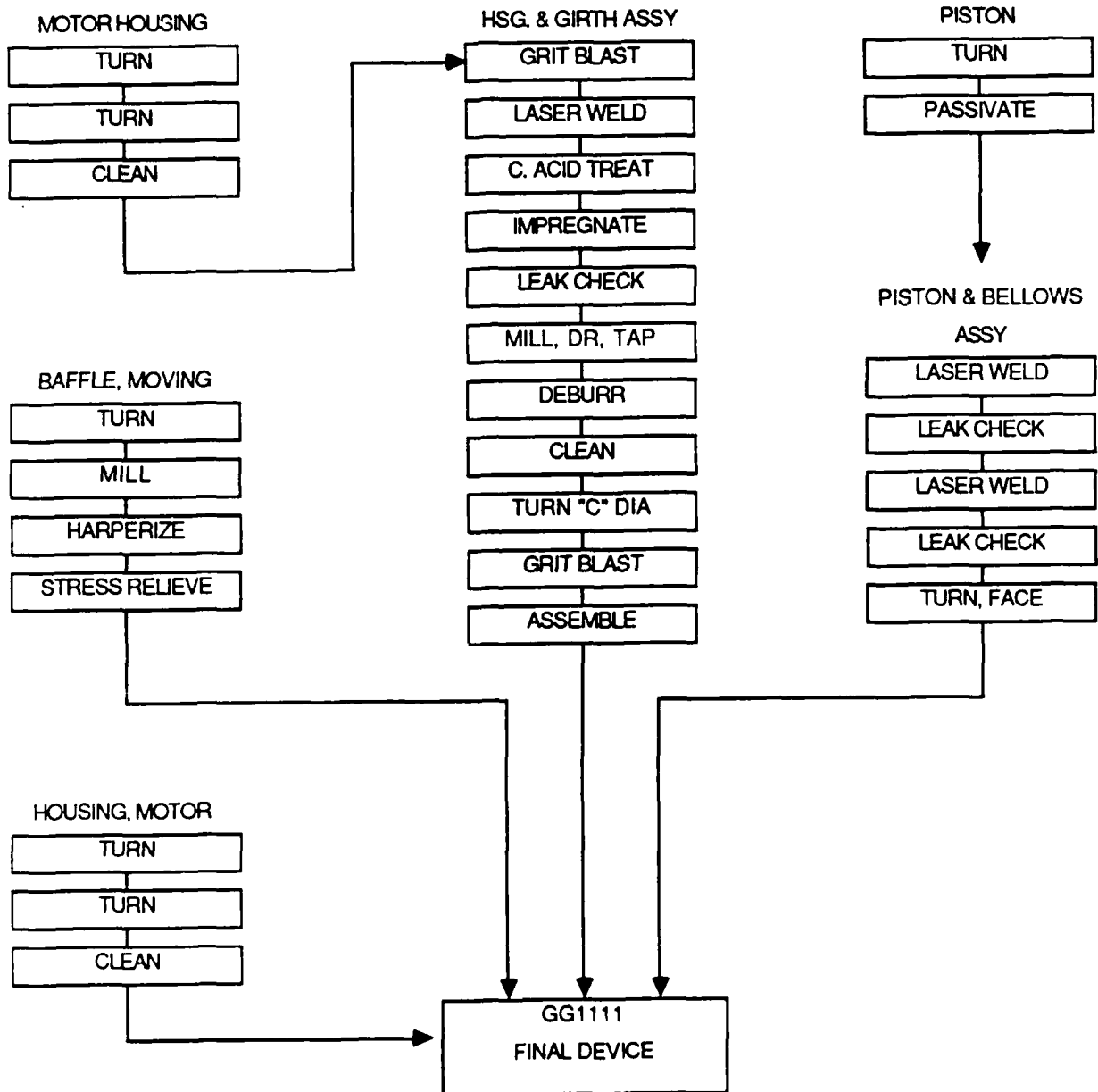


Figure 5.3 "To-Be" Housing/Girth Ring Process Flow

## SECTION 6

### PROJECT ASSUMPTIONS

The following ground rules and assumptions were made in the analysis of the "Girth Ring Cell".

- Precision Control Instruments (PCI) will provide the Production Engineering support to supply and troubleshoot the implementation of the laser welder into a Fab Fac production environment.
- Capital funds will be made available in the first quarter of 1989.
- The floor space required for this cell will be made available in the second quarter of 1989.
- Labor classification changes in this portion of the project are not limited by the present bargaining unit contract.
- The vacuum impregnation chamber and the vapor degreaser will be shared resources with the Laser Base and Walnut cells.
- The sealing problem of the housing and girth ring will be solved by utilizing the vacuum impregnation system assigned to the laser base cell.
- Design Engineering will restructure the piece part drawings to suit the methods of manufacturing.
- A one shift operation is based on 1700 standard hours per year.
- The "Girth Ring Cell" will be implemented in the first quarter of 1990.



## SECTION 7

### GROUP TECHNOLOGY CODING SYSTEM ANALYSIS

The "Girth Ring Cell" was formed as a result of the Group Technology technique's used to identify all the potential cells that could be formed. This approach is identified in Section 7 of the Project Overview.

## SECTION 8

### PRELIMINARY/FINAL DESIGN AND FINDINGS

#### INTRODUCTION

The approach to the formation of the "Girth Ring" cell follows the guidelines discussed in Section 3 of the Project Overview. Specific details on how this cell evolved from a preliminary design through a final design are discussed below.

#### PRELIMINARY CELL DEFINITION

In the development of this cell, the first step was to define the part families that would be selected to run in this cell. The key factors in the analysis were the machining and assembly operations. The high volume parts suitable for this work cell were identified. This amounted to six specific parts. At this point each process, for each part, was thoroughly analyzed to develop an understanding of the piece part, its final use and process constraints. Process improvements were identified by reducing operations and developing better process methods and technique's. Through this accomplishment, the information gathered on these parts were summarized and computerized.

These six components identified for this cell follow a very complex flow. They are fabricated partially by one department and moved between the departments according to layouts or process sheet instructions. The parts are moved from one end of the building to the other with long delays and long delivery schedules. This created an undesirable material flow condition and a difficult material control situation.

Some operations that are done in the Fab Fac machining area are repeated unnecessarily when it reaches the PCI assembly area. This was being caused through long staging delays and inefficient operation sequencing. With economics in mind, the best approach to improve this situation was to consolidate these operations into one segregated area. With this approach, a dedicated cell could be formed and benefits such as reduction in cost, lead times, Work-In-Process inventory and efficient material handling could easily be experienced.

#### EQUIPMENT AND TECHNOLOGY SEARCH

After forming the cell and defining the process requirements, the next step was to perform a thorough equipment and technology search. The findings from this process refinement indicated that our present technique's are the most efficient and economical means of manufacturing these six components. With these concepts established, the next best improvement for this cell was to integrate our existing equipment into a cellular manufacturing concept.

Through the preliminary analysis, it was decided to integrate an existing production laser welder and the machining operations into one segregated work area. With both PCI and Fab Fac having a demand for the production welder, it became unclear which area could utilize this piece of equipment more effectively. The technology transfer to the Fab Fac cell looked more appropriate because of its constant utilization. Inversely, PCI's unique machine requirements demanded that it remain in their assembly environment.

To resolve this problem, a series of meetings were held with the appropriate groups to come up with a solution. Through these meetings, the PCI production engineering department took on the task to identify, select, procure and integrate the laser welder that would best meet our process requirements. They concluded, the best solution would be for us to purchase a used laser welder that was available on the market. This welder would require us to upgrade the CNC controls, table positioning and the lens prior to running production parts on it. With the volumes and complexity of our process, this turned out to be a more economical decision. The remainder of the equipment and tooling selected for this cell already existed in the Fab Fac production area.

#### DISTRIBUTIVE NUMERICAL CONTROL

Distributive Numerical Control (DNC) is rapidly becoming a major step toward a closed-loop factory management system. With features like greater machine tool efficiency, greater shop up-time, enhanced shop flexibility, an important tool in group technology and computer aided process planning, the installation of this system was inevitable.

The DNC programming system will be on-line with the cell's machining center's. All operator and engineering changes, program updates and modifications will take place from the programming center. The digitized information will be transferred via a hard wired RS-232 connection. Active programming data will be stored in a hard disk memory which can be directly down loaded to the machining center's. This allows complete flexibility in part programming. This system is covered more thoroughly in the "NC Programming" section of this final report.

#### FACILITY LAYOUT

The manufacturing flow paths for the components dedicated to this cell were analyzed and a physical layout was developed. This was accomplished by identifying a material work flow, cell load, equipment utilization, manpower requirements, work space requirements, cell balance and a cell simulation study.

#### Work Flow

The material flow was identified by reviewing the computerized work center matrix. The base elements for this review were annual volumes, operator efficiency, operation complexity, workload balance and machine load. The flow paths were equipped with an adequate amount of equipment to satisfy the requirements of the parts.

### Cell Load

The workcenter matrix represented the cell load for each piece of equipment identified for the cell. This matrix was built by establishing the annual volumes and multiplying them by the run time in hours per piece. An assumption of 1700 standard hours per year is the basis for a one shift operation. This yearly hour base includes an 85% performance factor and a annual maintenance allotment. Through this analysis a determination can be made on the total production hours required for each piece of equipment.

### Equipment Utilization

Using the same methodology as described above, an equipment utilization factor was identified.

### Manpower Requirements

Based on the standards and sequence of operations in the process routings, a table was built to determine manpower requirements. The machine type and standard hours per piece were balanced to derive the direct labor requirement for each shift.

### Cell Simulation

A manual balance and simulation study for the components and equipment involved in this cell was done. Through this analysis, the proposed layout will not yield any bottlenecks or any down time. The simulation assures us that the throughput will follow the requirements as established in the preliminary design.

### Cell Layout

With a firm commitment on the space provided for this project, the next step was to identify the immediate work space requirements for this cell. This was accomplished through an economical analysis of each component and piece of equipment involved in this cellular approach.

### FINALIZE DESIGN

The design concepts of the "Girth Ring" cell were reviewed in detail and finalized. Provisions in the floor space were made to support the material handling and the material flow paths (ITM Project 20). The work cell area's were identified and finalized in the overall factory location layout. At the same time, any future growth was identified. Similar equipment resources were identified and located in areas that would suit both cell requirements. As a final step, the tooling and fixturing was integrated into the cell configuration. Figure 8.1 shows the final configuration of this cell.

# **GIRTH RING CELL LAYOUT AND MATERIAL FLOW TO BE**

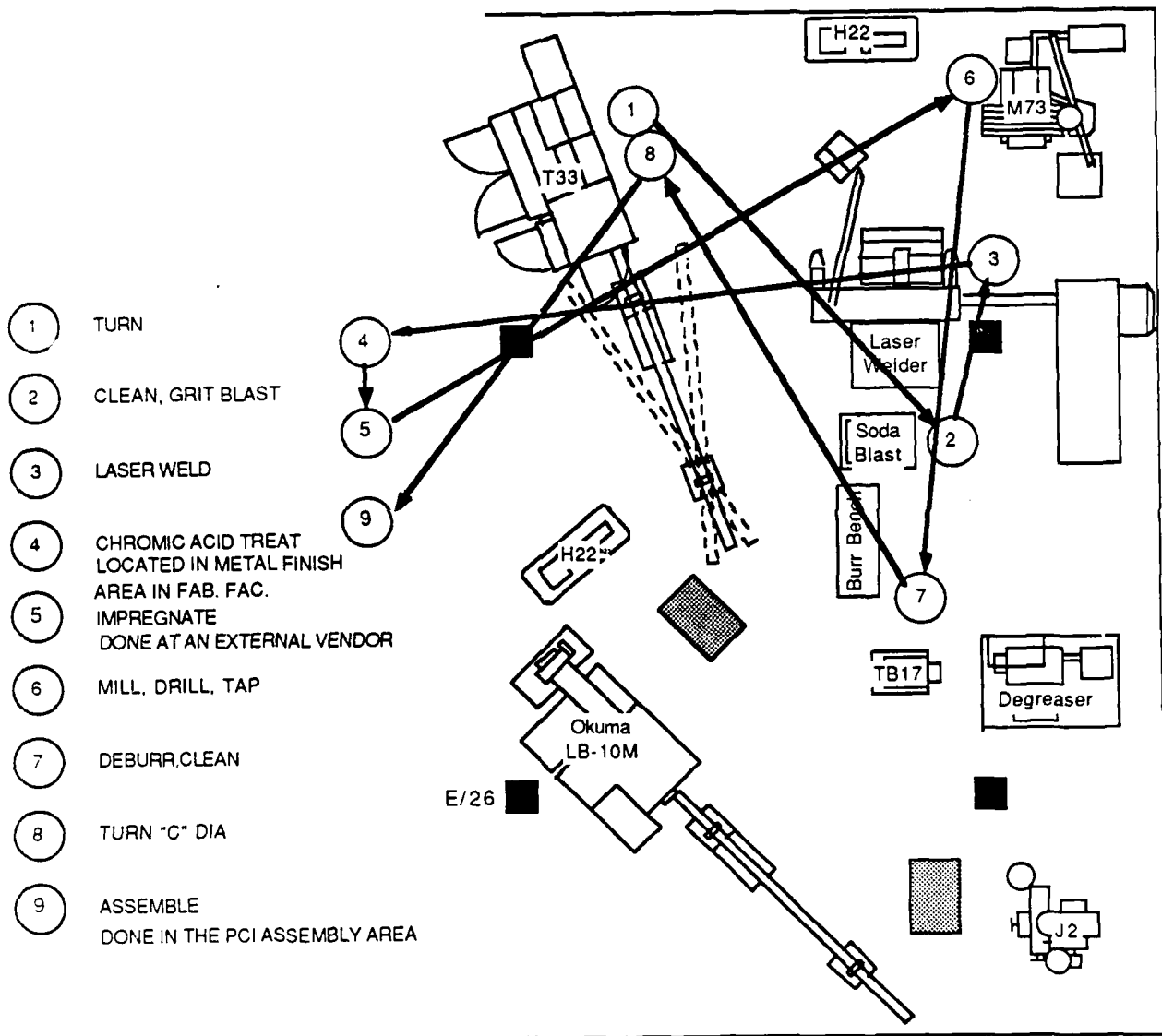


Figure 8.1 "To-Be" Girth Ring Cell Layout/Material Flow

## SECTION 9

### SYSTEM/EQUIPMENT/MACHINING SPECIFICATIONS

#### EQUIPMENT IDENTIFICATION

The "Girth Ring Cell" will consist of the following equipment:

1. CNC turning center.
  - Hardinge 4-axis superslant (current property of Honeywell Inc.)
    - Chuck and bar machine.
    - 1 5/8" diameter bar requirements.
    - 6 inch power chuck.
    - 16C collet capabilities.
    - Fanuc control.
    - DNC interface with RS-232 port.
2. CNC vertical machining center.
  - Bostomatic vertical machining center Model 312 (current property of Honeywell Inc.)
    - N/C dividing head (fourth axis).
    - DNC interface with RS-232 port.
    - Bostomatic SPC II control.
    - Table size- 12" x 44".
    - 12 tool magazine.
3. Multi-axis laser machining system.
  - N/C dividing head (fourth axis).
  - 500 watt laser.
  - 208 volt, 3 phase power.
  - Axis travel 39" x 27" x 27".
  - Carbon dioxide (CO<sub>2</sub>) pulsed and continuous wave.
  - On-line NC programming system.
  - DNC interface with RS-232 port.
  - Fanuc 6 control or compatible.
4. Vacuum Impregnation system.
  - Must meet Mil-Std-276 (Impregnation of Porous NonFerrous Metal Castings)
  - Resin transfer to the chamber.
  - Approximately a 24" diameter x 30" chamber.
  - Minimum resin temperature 59° F.
  - Water rinse.

5. Manual secondary turning lathe (current property of Honeywell Inc.).
  - Variable speed spindle.
  - 5C collet capabilities.
6. Self contained grit blast booth.
  - 10 to 150 micron particle size
  - 12" x 12" x 24" minimum chamber size
  - Powder flow of 40 grams/min.
  - Minimum air supply of 1.5 scfm
7. Vapor degreaser (current property of Honeywell Inc.).

## SECTION 10

### TOOLING SPECIFICATIONS

The "Girth Ring Cell" is created by integrating the existing equipment into one area. Such a rearrangement does not require any special tooling or fixturing. The tooling currently exists in today's production of the components. All new equipment will be purchased with standard tooling necessary to fulfill the equipment requirements for the cell.



## SECTION 11

### VENDOR/INDUSTRY ANALYSIS/FINDINGS

An industry survey was conducted to identify the companies that are capable of supplying the following items to meet the requirements of the "Girth Ring" cell:

1. Laser welder.
2. Self contained grit blast booth.
3. Vacuum impregnation system.

#### SELECTION CRITERIA

An industry search was conducted to identify the companies that would be capable equipment suppliers/integrators. In view of the many ongoing advances in machine tool automation and metal removal technology, we tend to think of modern mechanical manufacturing (CNC "Computer Numerical Control") as a highly productive and efficient process. The information for preparing this evaluation was obtained by:

- Conducting an extensive literature search (local and foreign), Thomas Register, technical journals, advertisements, etc.
- Contacting suppliers.
- Visiting a few companies.

In order to obtain detailed information, part drawings and, in some cases, sample parts were prepared and sent to selected companies to obtain first hand information and time estimates.

After review and assessment of the companies active in the market, several vendors were selected based on the following criteria (not listed by priority or importance):

- Capability to deliver.
- Servicing and training support.
- Machine requirements and capabilities.
- Project support in supplying pertinent data.
- Size and financial stability (as indicated by Dunn & Bradstreet reports).

Although tool cost, which reflects both the price of the equipment and its durability, is important, it is not necessarily the ultimate criteria. The ultimate criteria, depending on objectives, is either minimum total cost of the machining operation or maximum production rate. Equipment utilization is very high because everything necessary to produce the parts are in one location while one operator runs multiple machines in the cell for optimum productivity.

## EVALUATION CRITERIA

The vendors were supplied with part prints and generic equipment requirements. They were required to give time estimates, detail equipment specifications and current price quotes on the parts that were supplied to them. Following the receipt of the quotes and data, an equipment file and summary form was prepared for each piece of equipment. Figures 11.1, 11.2 and 11.3 contain the summary list of companies and individuals contacted (phone, mail contacts, visits and personal contacts) on the equipment involved in this survey. The data was reviewed and a final evaluation made based on pricing and machine specifications. The results (by equipment) of this analysis are described below.

### Laser Welding System

The data from the vendors for the laser welder was compiled and evaluated. With the cost on this piece of capital being so high, a decision was made to purchase a used system and retrofit it with a lens, CNC control and positioning table to suit the process requirements of the cell. The equipment selected was the Photon model V-1000 Laser welder. See Figure 11.1.

### Abrasive Jet Machining

The best selection for this piece of equipment was the AirBrasive #6500 system (reference Figure 11.2). This evaluation was based on the following strengths.

1. The ability to quickly interchange particle size.
2. Excellent dust collection capabilities.
3. Size and versatility.
4. Chamber capacity.
5. Work chamber dimensions.
6. The powder flow requirements are satisfactory to meet our process requirements.

### Vacuum Pressure System

With a limited number of vendors supplying this type of system, it was difficult to receive responses from the vendors (see Figure 11.3). The only supplier willing to provide Honeywell with a system quote was Imprex Inc. To insure the system would meet our requirements, the vendor agreed to run actual samples on their equipment prior to the purchase.

## GIRTH RING CELL EQUIPMENT SEARCH FORM

CELL NAME: GIRTH RING CELL (VENDOR STATUS BY 6/4/87)

PART # IN CONSIDERATION:

HOUSING, MOTOR  
GIRTH RING

GENERIC EQUIPMENT SPECIFICATIONS:

LASER WELDER SYSTEM THAT HAS THE CAPABILITIES  
TO WELD THE HOUSING & GIRTH RING, PISTON & BELLOWS ASSY.

EQUIPMENT & VENDOR	INFO SENT	RESPONSE	EQUIPMENT DESCRIPTION	REMARKS
LASERDYNE	YES	YES	MODEL 520 W/500 WATT PULSEABLE INDUSTRIAL CO2 LASER	BUDGETARY QUOTE \$ 226,100 TIME STD INCLUDED
HUFFMAN PRODUCTIVITY	YES	YES	MODEL HP-75  CO2 OR YAG	VERBAL QUOTE  \$350,000
PRODUCTIVITY INC	YES	YES	PHOTON MODEL V-1000 1000 WATT CO2 LASER WELDER  (USED WELDER TO BE RETROT FIT WITH TABLE, LENS, CNC CONTROLS)	VERBAL QUOTE  \$125,000

Figure 11.1 Laser Welder System Vendor/Industry Analysis Summary

## GIRTH RING CELL EQUIPMENT SEARCH FORM

CELL NAME: GIRTH RING CELL (VENDOR STATUS BY 6/4/87)

PART # IN CONSIDERATION:

HOUSING, MOTOR

GENERIC EQUIPMENT SPECIFICATIONS:

ABRASIVE JET MACHINING SYSTEM

EQUIPMENT & VENDOR	INFO SENT	RESPONSE	EQUIPMENT DESCRIPTION	REMARKS
SS WHITE PENNWALT	YES	YES	AIRBRASIVE 6500	BUDGETARY QUOTE \$2,100
ZERO BLAST-N-PEEN	YES	YES	BNP-30 DRY BLAST CABINETS	BUDGETARY QUOTE \$3,000
VAPOR BLAST MFG COMP	YES	YES	MODEL DFH-3030	BUDGETARY QUOTE \$6,130
COMCO INC	YES	YES	MICRO BLASTER MODEL 106	BUDGETARY QUOTE \$4,315

Figure 11.2 Abrasive Jet Machining System Vendor/Industry Analysis Summary

## GIRTH RING CELL EQUIPMENT SEARCH FORM

CELL NAME: GIRTH RING CELL (VENDOR STATUS BY 6/4/87)

PART # IN CONSIDERATION:

HOUSING, MOTOR  
GIRTH RING

GENERIC EQUIPMENT SPECIFICATIONS:

VACUUM-PRESSURE SYSTEM PER MIL-STD-276

EQUIPMENT & VENDOR	INFO SENT	RESPONSE	EQUIPMENT DESCRIPTION	REMARKS
IMPREX INC MILWAUKEE WISC.	YES	YES	IMPREX-ULTRA-SEAL MODEL PC-504 "B" SYSTEM	CAPACITY 71 CU. FT./HR APPROX 4 PROD LOADS/HR \$55,000
PRENCO CHICAGO		NO RESPONSE		
SINTER-SEAL BUFALO NY		NO RESPONSE		

Figure 11.3 Vacuum/Pressure System Vendor/Industry Analysis Summary

## SECTION 12

### EQUIPMENT/MACHINERY ALTERNATIVE

If the vendors evaluated are not suited to do this type of work or interface with selected equipment, the appropriate action would be to select a second vendor source. The companies listed below are identified as a second source for the equipment identified for this cell.

1. Laser Machining System  
Laserdyne Inc.  
Model 520

This machine was selected as an alternative because of the compatibility with the current equipment performing these operations.

2. Abrasive Jet Machining  
Zero Blast-N-Peen  
Model BNP-30

This abrasive blaster has the same characteristics as the primary selection for this application. The reason it was not selected as the primary candidate was its size configuration. Cost was also another disadvantage in this selection.

3. Vacuum Pressure System

With a limited number of vendors supplying this type of system, it was difficult to receive responses from the vendors. The only supplier willing to provide us with a system quote was Imprex Inc. To insure us that this system would meet our requirements, the vendor agreed to run actual samples on their equipment prior to the purchase.

## SECTION 13

### MIS REQUIREMENTS/IMPROVEMENTS

The "Girth Ring Cell" interfaces with the Honeywell Manufacturing System (HMS) and Process Management System (PMS) without modification to other systems hardware or software. These elements are discussed in further depth in Section 13 of the Project Overview.

Specific part dimensions will be captured by a Statistical Process Control (SPC) system within each cell. Complete details of SPC are covered in the Project 43 report.

## SECTION 14

### COST BENEFIT ANALYSIS/PROCEDURE

#### OVERVIEW

The Girth Ring Cell is a dedicated cell that will produce eleven machined components for Honeywell's GG1111 device. The major cost driver for this cell is the reduction in actual standard hours. This cost driver was identified using the methodology shown in the process diagram of Figure 14.1.

#### MANUFACTURING SCHEDULE

The manufacturing schedule for this cell used the marketing plan volume projections by product device. Attrition and part usage per device were accumulated to develop the ten year projections.

#### ACTUAL STANDARD HOUR SAVINGS

The methodology for deriving the "As-Is" and "To-Be" actual standard hours was followed as described in Section 14 of the Project Overview.

#### CAPITAL AND EXPENSE

The capital, recurring and non-recurring expense for the Girth Ring Cell are shown in Figure 14.2.

#### PROJECT SAVINGS AND CASH FLOWS

The savings to be realized by this cell exceed Honeywell's Military Avionics Division hurdle rate. The cell's cash flows are shown in Figure 14.3 with the assumption that capital is available per the implementation plan.



## COST BENEFIT ANALYSIS METHODOLOGY

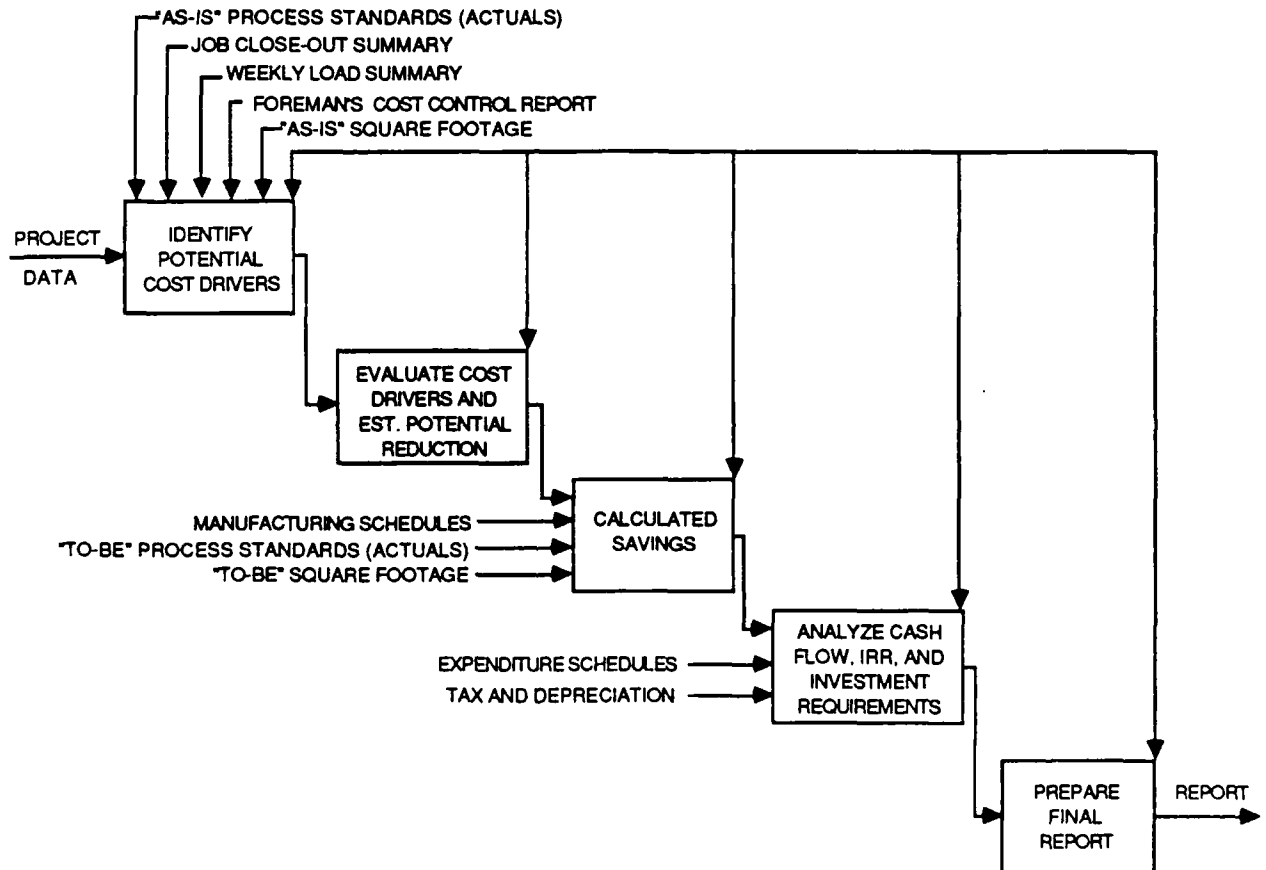


Figure 14.1 Girth Ring Cell Cost Benefit Analysis Methodology

**GIRTH RING CELL  
EXPENDITURE SCHEDULE**

	Cost	Capitalization Date
<b>CAPITAL COSTS</b>		
<b>MACHINERY COSTS</b>		
** Laser Welder	\$194,264	1989
** Impregnation Vacuum	\$73,686	1989
** Self contained grit blast booth	\$2,813	1989
** Area Preparation (Material)	\$18,058	1989
** Tooling (HI)	\$5,400	1989
	-----	
TOTAL MACHINERY COSTS	\$294,221	
<b>FURNITURE COSTS</b>		
** N/C Tool Storage Cabinet	\$1,398	1989
	-----	
TOTAL FURNITURE COSTS	\$1,398	
	-----	
TOTAL CAPITAL COSTS	\$295,619	1989
<b>EXPENSE COSTS</b>		
<b>NON-RECURRING EXPENSES</b>		
Area Preparation Labor (HI)	\$35,000	1989
Training (HI)	\$6,000	1989
N/C Programming	\$10,500	1989
Process Development Direct Labor	\$20,000	1989
Post Processor Development Direct Labor	\$6,480	1989
	-----	
TOTAL NON-RECURRING COSTS	\$77,980	1989
	-----	
TOTAL CAPITAL + NON-RECURRING	\$373,599	
<b>RECURRING EXPENSES</b>		
• Annual Maintenance (Mechanical)	\$3,500	
• Annual Maintenance (Computer HW)	\$1,165	
• Annual Maintenance (Computer SW)	\$583	
	-----	
TOTAL RECURRING	\$5,248	
<ul style="list-style-type: none"> <li>• Expense starts in year 2.</li> <li>** Costs contain a 15% contingency</li> </ul>		

Figure 14.2 Girth Ring Cell Expenditure Schedule

TECH MOD PHASE 2  
PROJECT 44 -- GIRTH RING CELL  
PROJECT CASH FLOW SUMMARY  
(\$000)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	TOTAL
Capital	\$295.6	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$295.6
Non-Recurring Expenses	\$78.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$78.0
Recurring Expenses	\$0.0	\$0.0	\$5.2	\$5.2	\$5.2	\$5.2	\$5.2	\$5.2	\$5.2	\$5.2	\$5.2	\$5.2	\$52.5
Total Savings	\$0.0	\$138.4	\$236.4	\$247.7	\$259.6	\$272.3	\$285.6	\$298.2	\$312.9	\$326.6	\$340.3	\$354.4	\$2,807.5
Depreciation	\$29.5	\$53.1	\$42.5	\$34.0	\$27.2	\$21.8	\$17.5	\$20.0	\$20.0	\$20.0	\$10.0	\$0.2	\$295.6

Figure 14.3 Girth Ring Cell Cash Flows

## SECTION 15

### IMPLEMENTATION PLAN

#### OVERALL IMPLEMENTATION PLAN

This implementation plan describes all the activities that are required to prepare the factory for the installation of this "Girth Ring Cell". Figure 15.1 shows all the elements of the implementation plan.

#### FACTORY MOVE COORDINATION

An anticipated problem as a result of the transition of the "Girth Ring Cell" into production is the impact on the factory productivity during the implementation phase. To eliminate the shutdown of production during this period, the following procedure was planned for this cell integration.

- Issue purchase order for the capital equipment.
- Run a production pilot with Precision Control Instruments on the laser welding of the girth ring to the housing. This will be accomplished by developing the process and training the responsible Fab Fac personnel.
- Rearrange and integrate the existing equipment to form the planned cell.
- Make minor modifications to the design and of the required tooling and fixturing for this cell.
- Receive and integrate purchased equipment in this cell.
- Test and debug the equipment.
- Phase all the selected components into production.

## GIRTH RING CELL IMPLEMENTATION SCHEDULE

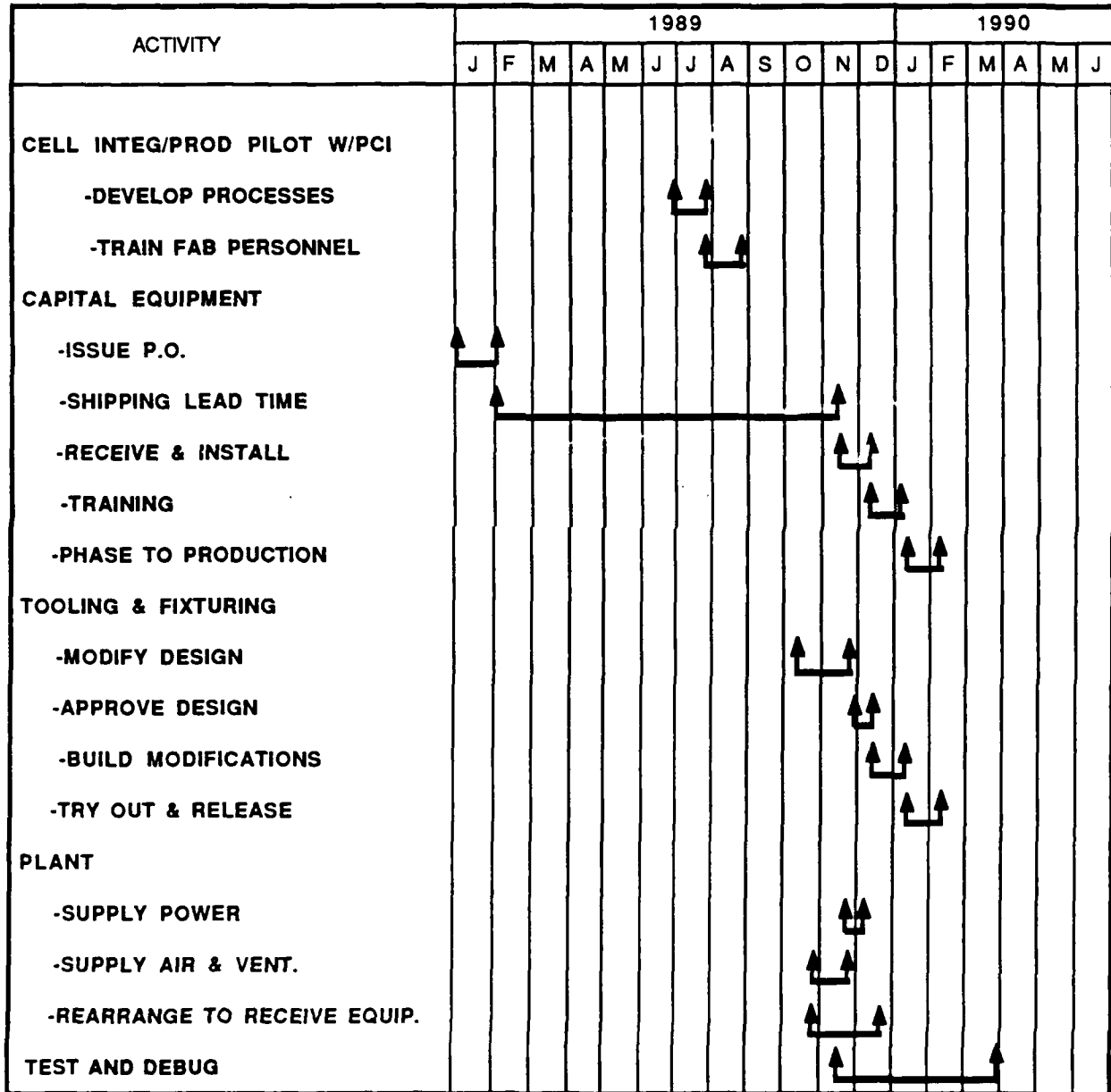


Figure 15.1 Girth Ring Cell Implementation Plan

## SECTION 16

### PROBLEMS ENCOUNTERED AND HOW RESOLVED

#### DEMAND FOR THE LASER WELDER

Upon completion of the final design analysis, a decision was made to integrate the laser welding and the machining operations into one segregated work area. With both PCI and Fab Fac having a demand for the laser welder, it became unclear which area could utilize this piece of equipment more effectively. The technology transfer to Fab Fac looked more appropriate because of its constant utilization. Inversely, PCI's unique machine requirements demanded that it remain in an assembly environment.

#### RESOLUTION

A series of meetings was held with the appropriate groups to resolve the issue. Through these meetings, the PCI production engineering department took on the task to identify, select, procure and integrate the laser welder that would best meet the process requirements.

#### VOLUME FORECASTS

It was difficult to pinpoint accurate volume forecasts in the product area because they operate on booked business only.

#### RESOLUTION

A letter of understanding was developed between the marketing and production groups to resolve what volumes could be expected if a projected price reduction was achieved.

#### PRESSURE EPOXY SEALING

As part of the existing process of laser welding the girth ring to the housing, an epoxy is applied to the housing and machined off to seal any pores that might cause a leak in the housing assembly. As a facet of this cell's approach, a vacuum impregnation system was included in this process to remedy this assembly problem.

#### RESOLUTION

A prototype run with a potential vendor will be done to determine feasibility. If this can't be accomplished through the vendor, accommodations will be made to implement the existing process into the cell.

## SECTION 17

### AREAS FOR FUTURE CONCERNS/DEVELOPMENT

#### FUTURE CONCERNS

##### Forecast Volumes

The equipment utilization and return on investment are based on the current projected sales volumes. If the volumes on this group of parts decrease, the content of this cell will have to be rescoped.

#### FUTURE DEVELOPMENT

If the volumes for the components dedicated to this cell increase in the coming years, two areas for future development arise:

1. To further eliminate set-up time in the cell, a quick change chucking system could be adapted to the turning center.
2. A robotic load/unload system, interfacing with the laser welder, mill and lathe will reduce operator material handling time.

These concepts have been discussed and will be investigated in detail when the present cell has been installed. The benefits derived from these two systems would mean significantly greater reductions in labor costs and improvements in material flow resulting in lower product cost.

## PROJECT 44

### MODEL/SHORT RUN SHOP AND FLEXIBLE MACHINING AREA

#### SECTION 1

#### INTRODUCTION

The Model/Short Run Shop and Flexible Machining Area (Flex Shop) are part of the Fabrication Facility (Fab Fac) business area. The Model/Short Run Shop is located in Honeywell's Stinson/Ridgway (S/R) and St. Louis Park (SLP) facilities. The Flex Shop is located in the Stinson/Ridgway building. Fab Fac is part of Inertial Instruments Operations (IIO) within Honeywell's Military Avionics Division (MAvD). The Model/Short Run and Flexible Machining areas performs machining, fabricating and model/tool making tasks for MAvD business groups and Commercial Avionics Division (CAvD) on a regular basis. Similar tasks are performed for any requesting Honeywell business group on an exception basis. The mix of Model/Short Run Shop work ranges from developmental precision gyroscope parts, to a high variety of low volume parts, one of a kind models, tools and unexpected spares orders. These parts consist of a variety of materials, from aluminum to cold rolled steel, stainless steel and various nickel alloys. The size range on this group of parts varies from very small intricate parts, approximately .10 cubic inches to castings or raw material hogouts that are 8.0 cubic inches. The type of tolerances that are being held on these parts range from  $\pm 0.0002$  inches on diameters to fractional dimensional tolerances. The shops are not profit centers, all work performed is cost transferred to the internal customer at actual labor expended.

Implementation of the Model/Short Run Shop and Flexible Machining Area will focus production equipment and processes to fulfill unique customer requirements. The Model Shop will produce models, tools and special projects with reduced lead time and costs. By preplanning, scheduling and simultaneously executing multiple tasks by specialists on modern CNC machine tools, both costs and lead times will be improved. The Short Run Shop, manned by both Toolmakers and skilled CNC production operators, will perform set-up and run on low quantity parts. The skilled workforce, used to challenging requirements and changing part specifications will complete non-repetitive type jobs with smaller learning curves than would be found in average production situations. The Flexible Machining area will produce parts of moderate volume that are released with predictable regularity. Since jobs follow a known process path on fixed intervals, both scheduling and training requirements are reduced. The stabilization of production factors will result in predictable, timely deliveries and reduced product cost.

The two shops will have several union work groups and labor grades for each workforce, and will share capital equipment to improve overall utilization and improve costs. These two areas are discussed in a single segment due to this unique blending of capital and human resources.



## SECTION 2

### PROJECT PURPOSE/OVERVIEW

Implementation of this segment of Project 44 will re-scope the Tool Room/Model Shop, and create a Flexible Machining Area. It will radically change the processes, equipment and scheduling methods. Tools, models and low volume part costs will be reduced and lead times shortened. The new shops will better meet the objectives of each of the Honeywell business groups they serve. The basic functions of the areas are:

- Tool Room/Model/Short Run Shop - Short run parts, models, tools and special projects will be produced expeditiously with competitive overall costs. By pre-planning, scheduling and simultaneously executing multiple tasks by specialists on modern CNC machine tools, both costs and lead times will be improved. The Short Run Shop will complete non-repetitive type jobs with smaller learning curves than would be found in average production situations.
- Flexible Machining Areas - Machine repeat parts with moderate volume. The current single discipline departments will be replaced by a focussed Turning Grinding and a Milling Drilling area. The stabilization of production factors will result in predictable, timely deliveries and reduced product cost. The responsibility for a part's quality, cost and schedule will be the responsibility of one department.

The implementation has high financial return with relatively low risk. The project will be phased in over a three year period. CNC equipment will be transferred from the current NC Machine Shop as the Pallet Cell is installed. This allows time for work flow and organizational changes to be implemented prior to major capital purchases.

## SECTION 3

### TECHNICAL APPROACH

#### INTRODUCTION

The technical approach for the Fabrication Facility (Fab Fac) area is detailed in Section 3 of the Project Overview. In this report only those items that are unique or specific to this project segment are included.

#### FLEXIBLE MACHINING AREA

##### Introduction

Engineering teams were formed to evaluate work cell potential for the Dither Spring, 1 1/2" Bar, T-Bar and Sheetmetal families of parts. The parts analyzed in the turning portion of the proposed cell were re-evaluated as part of the 1 1/2" Bar Cell study after the T-Bar study was concluded. The Sheetmetal Cell, which supports the Model/Short Run Shop and reports administratively to the Flexible Machining Area is fully discussed in it's separate segment of this final report. The investigative base for all of the cells discussed here was the parts list and preliminary design concepts developed by the Project 44 core team. The technical approach to the evaluation/investigation was as follows:

##### Cell Concepts Analyzed

1. A matrix was structured to show total hours spent on each machine for all parts currently being manufactured and the current equipment used. The project core team supplied the potential areas for improvement, actual labor costs, and a rough preliminary design.
2. An equipment/technology search was conducted to evaluate processes that would result in cost, delivery and/or lot yield improvements.
3. Preliminary time estimates, for proposed equipment or processes, were developed. Process flows and preliminary design/concepts were analyzed, modified and reanalyzed. When volumes were insufficient to meet concepts, additional parts of the original investigative parts base were added to the cell parts base and the cell concepts re-evaluated. Representatives of the Fab factory teams, supervisors and certain shop specialists participated in vendor visits, sales demonstrations, concept discussions, etc. These evaluation participants provided a two way communication vehicle to gauge and understand factory concerns to project proposals.

4. Marketing forecast of parts selected for probable inclusion in the cells final design were obtained by the Inertial Instruments Operations (IIO )Tech Mod Program Manager. These volumes, proposed equipment, time standards (modified by actual labor experience in the area of machine installation) and anticipated system constraints were used to complete simulation of the proposed and final designs.
5. Developed work cell layout, labor costs and cell load equipment utilization to determine percentage of load on each machine.
6. Calculated internal rate of return on the capital investment required by departmental and division approved methodology.
7. Cell concepts, designs, internal rate of return and equipment utilization were jointly reviewed on a weekly basis by the core team. The Core team consisted of the Project 44 Program Manager, Production Engineering (PE) Supervisor, Industrial Engineer, PE Capital Specialist and team captain of each project segment discussed in the final report.
8. The 1 1/2" Bar cell, turning parts of the T-Bar cell and Dither Spring Cell were merged into the Flexible Machining Area concept. This team decision was made to improve financial returns by improving utilization of proposed cell equipment.

#### Flexible Machining Area Investigation

An engineering team was formed to evaluate a Flexible Machining Area concept for the parts, identified by the core team, having high annual shop hours usage that were not being evaluated as a possible work cell candidate. The investigative base was the parts list and preliminary design concepts developed by the Project 44 core team. The technical approach to the evaluation/investigation was as follows:

1. The project parts base matrix, with cell potential parts removed, was sorted by critical manufacturing resource (work center). The total hours/year by resource were analyzed to determine process flow paths.
2. Parts with process flow similarities were removed from the matrix and further analyzed in sub sets by process flow.
3. Higher volume (by dollar value) subcontract parts were reviewed and added to the appropriate process flow path groups.
4. An equipment technology search was conducted to evaluate equipment and processes that would result in cost, delivery and or lot yield improvements.

5. Preliminary time estimates, for proposed equipment or processes, were developed. Process flows and preliminary design/concepts were analyzed, modified and reanalyzed. When volumes were insufficient to meet concepts, additional parts of the original investigative parts base were added to the cell parts base and the cell concepts re-evaluated. Representatives of the Fab factory teams, supervisors and certain shop specialists participated in vendor visits, sales demonstrations, concept discussions, etc. These evaluation participants provided a two way communication vehicle to gauge and understand factory concerns to project proposals.
6. New, existing and future capital or resource needs were defined for each process line. Additional resources, to support the general area and requirements for support of the secondary operations were identified.
7. After removal of parts proposed for other cells final design, marketing forecast of parts remaining in the matrix were obtained by the IIO Tech Mod Program Manager. These volumes, proposed equipment, time standards (modified by actual labor experience in area of machine installation) and anticipated system constraints were used to complete simulation of the proposed and final designs.
8. Finalized process flow layouts, labor costs and equipment utilization on each major new proposed machine and supporting resources.
9. Process line concepts, designs, internal rate of return and equipment utilization were jointly reviewed on a weekly basis by the core team. The core team consisted of the Project 44 Program Manager, Production Engineering Supervisor, Industrial Engineer, PE Capital Specialist and team captain of each project segment discussed in the final report.
10. A decision was made to merge a Flexible Machining Area concept with the Model/Short Run Shop. This team decision was made to improve financial returns by improving utilization of proposed equipment in each area and to eliminate a substantial overlap of equipment and resources.

#### MODEL SHOP AND SHORT RUN SHOP

An engineering team was formed to evaluate a Model/Short Run Shop concept for the parts identified by the core team. Parts with "As-Is" actual set-ups that exceeded run time, tools, models, emergency work and special projects were proposed to become the work of the Model/Short Run Shop. The Flexible Machining Area was merged with the Model Shop investigation to reduce overall capital costs and improve asset utilization by sharing equipment between the two departments. The investigative base was the parts list and preliminary design concepts developed by the Project 44 core team. The technical approach to the evaluation investigation was as follows:

1. The parts with similar process flow characteristics were removed from the parts list matrix for Flex Shop final design development. The remaining parts on the list were left with the balance of the Fab shop hourly load for Model Shop design evaluation. These low volume, high variety parts were approximately 20% of the total Fab workload.

2. Analyzed, by observation and operator discussions, the Model Shops work and low volume parts run throughout the rest of Fab. The tools, fixtures and current processes/technology levels were observed and recorded.
3. Studied and clarified the job processing procedures; determined the reasons for delays and effects on the output of the Model Shops; and the utilization of the equipment.
4. Developed a method to determine the yearly shop load and capacity in terms of types of operations and equipment. Informal meetings were held with Toolmakers. Project preliminary concepts, goals and data gathering methods were shared. A data collection form, to be used by every operator for all work, was developed with active operator participation. The form was used to gather a ten week sample of all work done in the Model Shops. Results of the study were shared with the operators in a follow up meeting.
5. Established the "As-Is" data base from the information gathered. The data was factored and interpolated to determine the "As-Is" yearly shop load.
6. Operators and Model Shop Supervisors recorded observations and the ten week survey data was incorporated in a final design. The design determined the numbers of equipment required to support each type of machining operation in the Model Shops on a one shift operation basis.
7. The final design was presented to Fab Fac senior management and staff. Equipment, identified as possible surplus, was authorized to be temporarily stored in a warehouse to test concepts.
8. Equipment specification lists for all equipment to remain in or be purchased for the area were prepared.
9. Prepared the "To-Be" layouts for the Model Shops and Short Run Shops. Brought to senior management's attention building use issues that required resolution to design effective internal work flows of materials in and inter-department interactions.
10. Prepared final design and area layout. Reviewed equipment requirements and layout with area supervisors and all levels of Fab Fac management.
11. After approval of final design, an implementation schedule was prepared for the procurement of new capital equipment, surplus of redundant equipment and installation plan for area required, equipment and resources.

## SECTION 4

### "AS-IS" PROCESS

#### INTRODUCTION

The "As-Is" conditions for the Fabrication Facility (Fab Fac) area in general are detailed in Section 4 of the Project Overview. This section details only those items that are unique or specific for the Flexible Machining Area and Model/Short Run Shop.

#### FLEXIBLE MACHINING AREA AND SHORT RUN SHOP

The Flexible Machining Area and Short Run Shop do not exist in an "As-Is" condition, as they are created as a result of the Phase 2 study. The parts, and the manufacturing environment are discussed in Section 4 of the Project Overview. The conditions described below are direct excerpts from that section of the report. They are replicated here for clarity.

The Fabrication Facility (Fab Fac) is located on the first floor of Honeywell's Stinson/Ridgway and the second floor of the St. Louis Park facilities. These facilities manufacture/supply approximately 70% of the mechanical components and some of the tooling and models used by other Honeywell Avionics departments in Minneapolis. These departments include, Microwave Systems Production (MSP), Test Systems Production (TSP), Target Systems (TS), Precision Control Instruments (PCI) and Flight Management Systems (FM).

The Fabrication Facility operation is comprised of four functional areas - Production Control, Production Engineering, Quality Assurance, and Fabrication Facility (Fab Fac Manufacturing). The plant layout is shown on Figure 4.1. Fab Fac has a typical job shop environment with many small lot sizes and a multitude of different part structures. More than 500 orders are processed every month, with an average of approximately 200 parts per order. There is a total of approximately 1800 different part groups produced in Fab Fac. Of these, 135 part groups make up 80% of the total annual quantity delivered. Very little dedicated equipment is used, resulting in significant set-up costs. This results in many general-purpose machining operations on a variety of materials ranging from mild steel, aluminum, nickel, iron, brass, magnesium, invar and stainless steel. These parts are often machined to tight tolerances of .0001 inches or better.

The Fabrication Facility is divided into five departments:

1. Tool Room/Model Shop (Stinson/Ridgway and St. Louis Park)
2. NC/CNC Milling/Drilling
3. Miscellaneous Machining/Burring/Blue Coat/Sheetmetal
4. Turning/Grinding
5. Metal Finishing

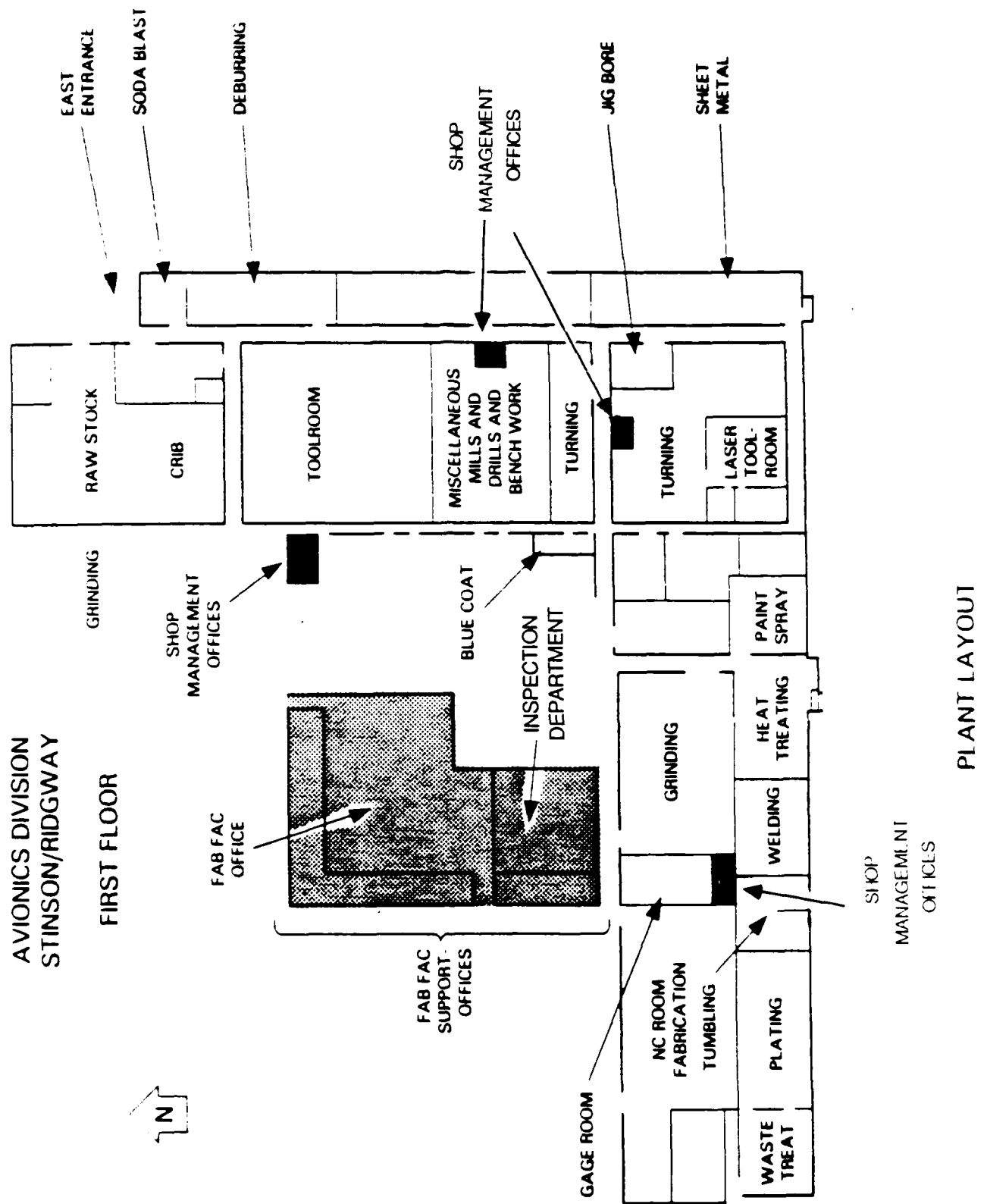


Figure 4.1 "As-Is" Fabrication Facility Layout

The Fabrication Facility is divided into five departments with manufacturing at both the Stinson/Ridgway and St. Louis Park plants. Proportionate space allocations are shown on Figure 4.2.

All work orders for Fab Fac are generated through the computer "Factory Order Generation" system (FOG) and distributed through a shop packet, tool make order, or express order. Components are fabricated entirely by one department or move between departments according to detailed process documents and summary sheet instructions (see Figure 4.3).

Material does not follow a simple flow through the shop. Process flows are complex, and orders are routed to various work stations in order to generate their particular shape.

Process instructions describe the sequential order in which manufacturing has to perform the various tasks of machining and finishing of components. They also include detailed specifications for required tooling, fixturing, and critical machining data and also select the equipment on which the process is to be performed. For planning and scheduling purposes, alternate equipment is sometimes used. Detail sheets have time standards for each of the process steps or operations based on time elements developed by Industrial Engineering.

Inspection operations are performed at specified process steps as defined by process summary sheets. All components receive final inspection before they are shipped. Tooling and fixtures are returned to designated storage areas after their related operations are completed. Gauges are returned to inspection for calibration. Cutting tools are returned to stores to be sharpened and prepared for the next use. Expendable drills are not returned or reused for manufacturing operations.

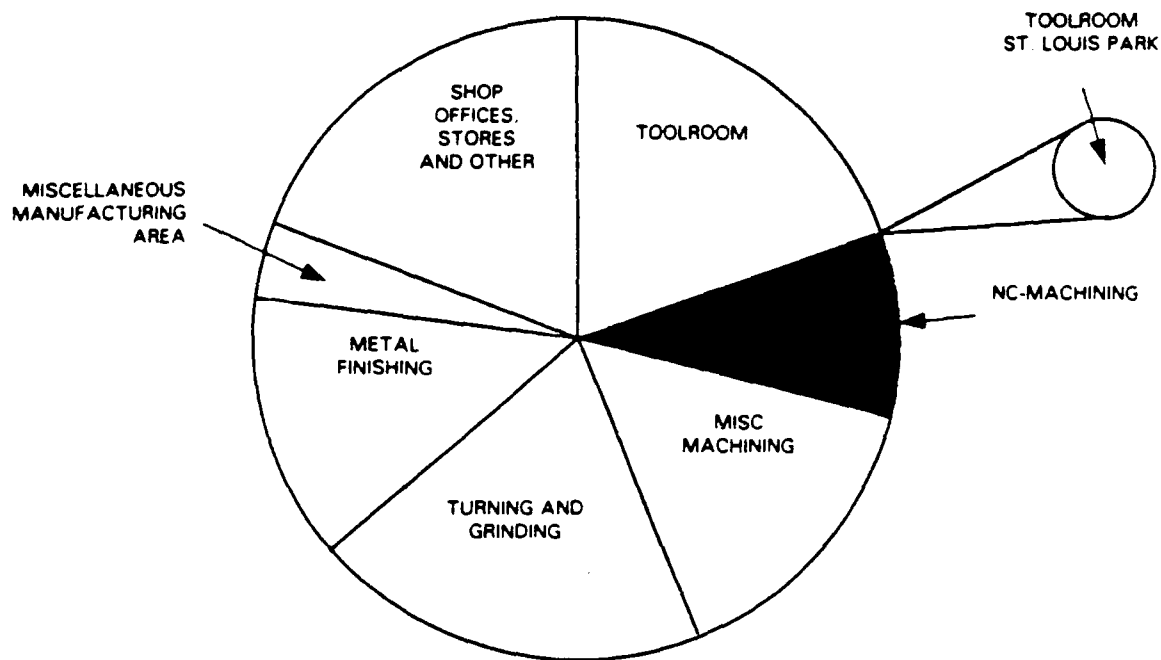
All movements of job packets, orders and materials are done manually by hand-carry or hand cart. These moves are performed by stores personnel after the work centers/work stations finalize their operations. When completed, they are placed on shelves conveniently located throughout the manufacturing area for Work-In-Process and raw material.

One of Fab Fac's functions, the manufacture of tools and models, is performed in dedicated areas of both facilities (Stinson/Ridgway, St. Louis Park). These areas supply Honeywell Avionics departments with tools, fixtures, or models/prototypes related to internal programs.

NC programming is a shared function performed either by Model Shop programmers or Production Engineers. Production Engineers provide technical guidance and review NC programs generated by Model Shop programmers, which are used in Production.

The majority of NC programming is done manually by development of cutter center line paths. Automatically Programmed Tools (APT) based computer assist is available on a time share basis but is little used. There is significant potential for reduced cost for both conversion of jobs to new equipment and updates to NC tapes caused by Design Engineering change orders. CNC programming for the Tool Room and Model Shop machines are the complete responsibility of the Tool Room and Model Shop personnel.





NC-MACHINING OCCUPIES THE SMALLEST  
PORTION OF THE SHOP AREA SPACE DISTRIBUTION

Figure 4.2 "As-Is" Fabrication Facility Space Distribution



Most of the more than 360 listed machine tools or equipment in the Fab Facility are conventional or manual machines. Less than 5% are numerically controlled. Manual operations are performed at the numerous work benches located throughout the Fab Fac department. Figure 4.4 shows the average age of the aforementioned machines presently in use. The "As-Is" equipment survey shows that on average the equipment is over 20 years old and the majority should be replaced.

#### COMPUTER APPLICATIONS

Fabrication Facility has both CNC and NC controlled machine tools. Ten CNC machines and two NC machines with before tape reader memory expansions can be connected via RS232 link to DNC. Other NC machines would require various degrees of modification, but all are convertible to DNC.

NC programming is aided by a generic post processing (Micro-Numeric) system equipped with minimal options. The system is used equally for business as well as tape creation of editing. UCCEL (APT) is available on a teletype terminal on a timeshare basis.

Six personal computers (TRS-80, Apple and Columbia) are used by Production Supervision and Production Engineers. They use modified generic programs to produce local control reports. Many process layouts (controlled production instructions) are produced, several with graphics.

Since Honeywell recognized the importance of computer-integrated manufacturing systems prior to the start of Honeywell's Tech Mod program, there are several ongoing MIS projects, each of which provides an essential CIM building block. Existing systems projects include:

- HONEYWELL MANUFACTURING SYSTEM (HMS): A packaged, integrated manufacturing system including inventory record management, manufacturing data control, MRP II, master production scheduling, purchased material control, capacity requirements planning, shop floor control, and statistical order forecasting. This project is being accomplished through close cooperation between Honeywell MAVD and Honeywell Information Systems (HIS) Group which developed the HMS package. HIS is involved in the project to ensure that the special government-related needs of MAVD are satisfied by HMS. A current MAVD pilot program in a user area is being used to test the HMS package and develop the necessary modifications. The result of this close cooperation will be the development of a manufacturing package that will meet the special needs of MAVD and other government contractors.
- PROCESS MANAGEMENT SYSTEM (PMS): A custom-made paperless Production Engineering tool designed to allow on-line entry and modification of parts lists, detail summaries, layouts, and process detail.
- FACTORY DATA COLLECTION (FDC): A custom-made system designed to automate factory data collection through the use of data entry terminals, bar code readers, and voice data entry systems. It is to be integrated with HMS to increase data collection efficiency.
- CAMAID: A series of CAD/CAM/CAE projects to automate design and Production Engineering tasks. It includes plans to integrate and automate the design-to-production transition and provides for direct links to DNC equipment.

PROCESS	MACHINE AGE FROM-TO (YEARS)	AVERAGE AGE (YEARS)
MILLING JIG BORE TURNING DRILLING GRINDING DRESSING FORMING NOTCH/PUNCHING SAWING BENDING/ROLLING SANDING HEAT TREATING WELDING BLASTING OTHER	<b>1-42</b>	<b>22.2</b>
TOTAL	<b>1-42</b>	<b>22.2</b>

**EQUIPMENT AGE**

Figure 4.4 "As-Is" Fabrication Facility Equipment

## MODEL SHOP

The Model Shop produces tools and models, and supports special projects and limited production. Production work is either planned (by FOG and PMS summaries) or unplanned. No planned production work is performed in the St. Louis Park (SLP) Tool Room. For unplanned piece parts completed at Stinson/Ridgway Tool Room, hand written control documents are prepared by Production Control, Quality Engineering and Production Engineer. These hand written orders, for piece parts, are controlled by a FOG job number for tracing, records retention and collection of actual costs. These document originals are stored manually by Production Control for use on future orders. Both Model Shops accept "express orders" from walk-ins, emergencies and support work from requesting areas.

The typical flow path of a job through the Model Shop is shown in Figure 4.5. The two basic components, pre-release activities and build are discussed below.

### Pre-Release (Office) Activities

Tool Make (TM's) orders, tool prints, or concepts, are prepared for the Toolmaker by Tool Design. Special materials, not available in the Fab area tool crib, are requisitioned by purchase orders originated by Production Control. Some expedited material items are purchased by runner and cash pick up, with documentation and proper forms following. There is no automated priority system to control individual job needs. Tool components machining requirements or labor needed to produce are not systematically prioritized. There is no formal linking of tool delivery requirements for a new job in Fab production. When parts or projects are prioritized, usually by an act of management, it is at the expense of less vocal customers. When all known build constraints have been satisfied and job tracking documents (for record retention) are manually prepared, the TM is released to the Model Shop. Production Control offers limited support to the SLP Tool Room. The SLP supervisors are responsible for pre-release tasks for most jobs. There is some limited, usually special projects, coordination between the two Model Shops.

### Tool Build Activities

The build time for a tool make order (TM), as estimated by many different individuals with authority to order from the Model Shop, is reviewed, re-estimated and logged by the group leader. Gross differences in completion costs are resolved between Production Control and the customer. Regardless of whether a TM estimate has been formally updated, the group leaders estimate is logged with the job number in a records book. This book estimate is compared with actual labor costs for use as an shop performance indicator.

The group leader assigns a Toolmaker to complete a job. The usual sequence is for the Toolmaker to study the job to determine a process. The Toolmaker then coordinates all phases of the tasks of ordering material to be cut in the tool crib, sequentially running all phases of manufacture, and parts inspecting/accepting and taking delivery of the completed order to the group leader. The group leader forwards order close-out information to Production Control. Production Control does required record retention and closes the order.

# **AS IS JOB PROCESSING (MODEL SHOP)**

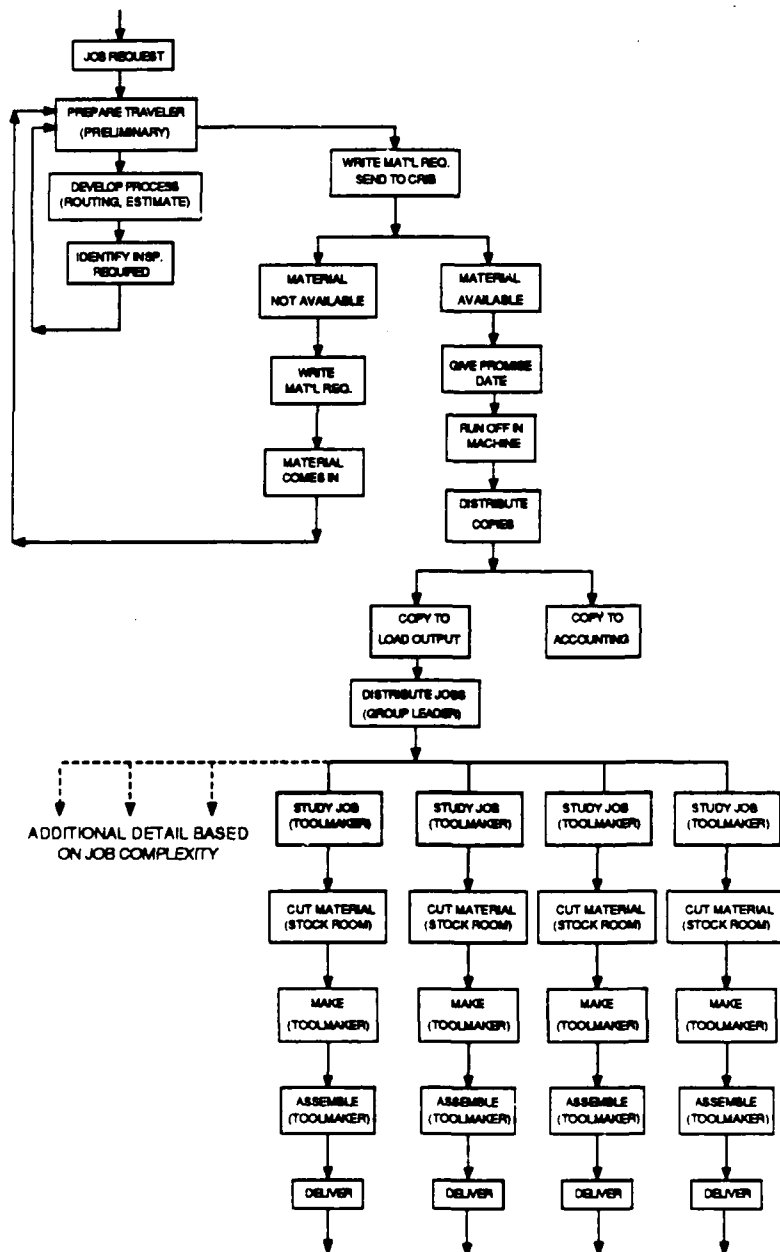


Figure 4.5 "As-Is" Model Shop Job Processing

Inefficiencies of man/machine utilization are inherent in this process. Each Toolmaker must fight for priority to use a particular machine with his fellow workers. There are delays and unproductive lulls as material is being prepared or an operation is completed by another Fab area. Since the process is sequential, lead times cannot be compressed for non-management expedited jobs. There is an overabundance of planning benches and shortages of capital equipment. The process results in an artificial lack of capacity situation, delays in completion of the jobs and poor utilization of the human and machine resources.

## SECTION 5

### "TO-BE" PROCESS

The "To-Be" conditions for the Fabrication area in general are detailed in Section 5 of the Project Overview. Portions of that report segment have been replicated below for clarity. This section details only those items that are unique or specific for the Model/ Short Run Shop and Flexible Machining Area.

#### GENERAL

The Fabrication Facility (Fab Fac) business remains in the Stinson/Ridgway facility. A small Tool Room remains at the St. Louis Park (SLP) facility. Fab Fac performs machining, fabricating and model/tool making for Honeywell internal customers. Fab Fac is not a profit center. All work performed is cost transferred to the business group served at actual cost expended to produce. The mix of work ranges from high volume, precision gyroscope parts, to a high variety mix of moderate volume parts, to one of a kind models and unexpected spares orders. Fab Fac has been reshaped to meet the customer requirements and their diverse work load input.

The Production Control area has been upgraded by implementation of all standard modules of the Honeywell Manufacturing System (HMS). Tools, models and rush jobs are manually processed into the HMS system to allow full control, scheduling, and allocation of machine resources in all areas. All work is prioritized. Tool fixtures, materials, gauges, machines, and human resources are scheduled for minimum delivery schedules. High, moderate, and low volume orders together with tools, models and unexpected spares orders are effectively controlled and scheduled by the Capacity Requirements Planning (CRP) module of HMS.

The factory departments are monitored through the use of an automated Factory Data Collection (FDC) system. This data is transmitted to the shop floor control module contained within HMS. Status update information is available to floor management, internal customers and other users of the system. The diverse production needs of the internal customer base are met without disruption or senior management directed relocation of Fab Fac's manufacturing resources.

The total area for Fab Fac will be reduced by approximately 7,200 from the "As-Is" condition. Figure 5.1 shows the allocation of Fab Fac in the Stinson/Ridgway Facility and Figure 5.2 of the functional and support areas. Figure 5.3 shows the area reduction at the SLP Tool Room located in the St. Louis Park facility.

The space reduction is a result of the following: fewer machines; machines with increased capabilities; interdepartment sharing of machine resources; pre-planning and online scheduling of all fabricating work; reduced staging areas; part inspection is completed at the manufacturing site for most parts; dedicated, continuous product cells for high volume parts; work and capability consolidation of St. Louis Park Tool Room with Stinson/Ridgway Tool Room/Model Shop; and use of Model Shop for low volume production parts (see Figure 5.4).



MGMT SUPPORT

RLGM OFFICE

RLGM COMMON  
GG1320  
GG1342  
GG1328

RLGM STOCK

EQUIP/NURSE

PCI MISC

ADV PROD

COMPUTER

MET LAB

FAB

DOCK

TRADES

FIRST FLOOR

**HONEYWELL INC.**  
**Military Avionics Division**  
**Stinson/Ridgway**

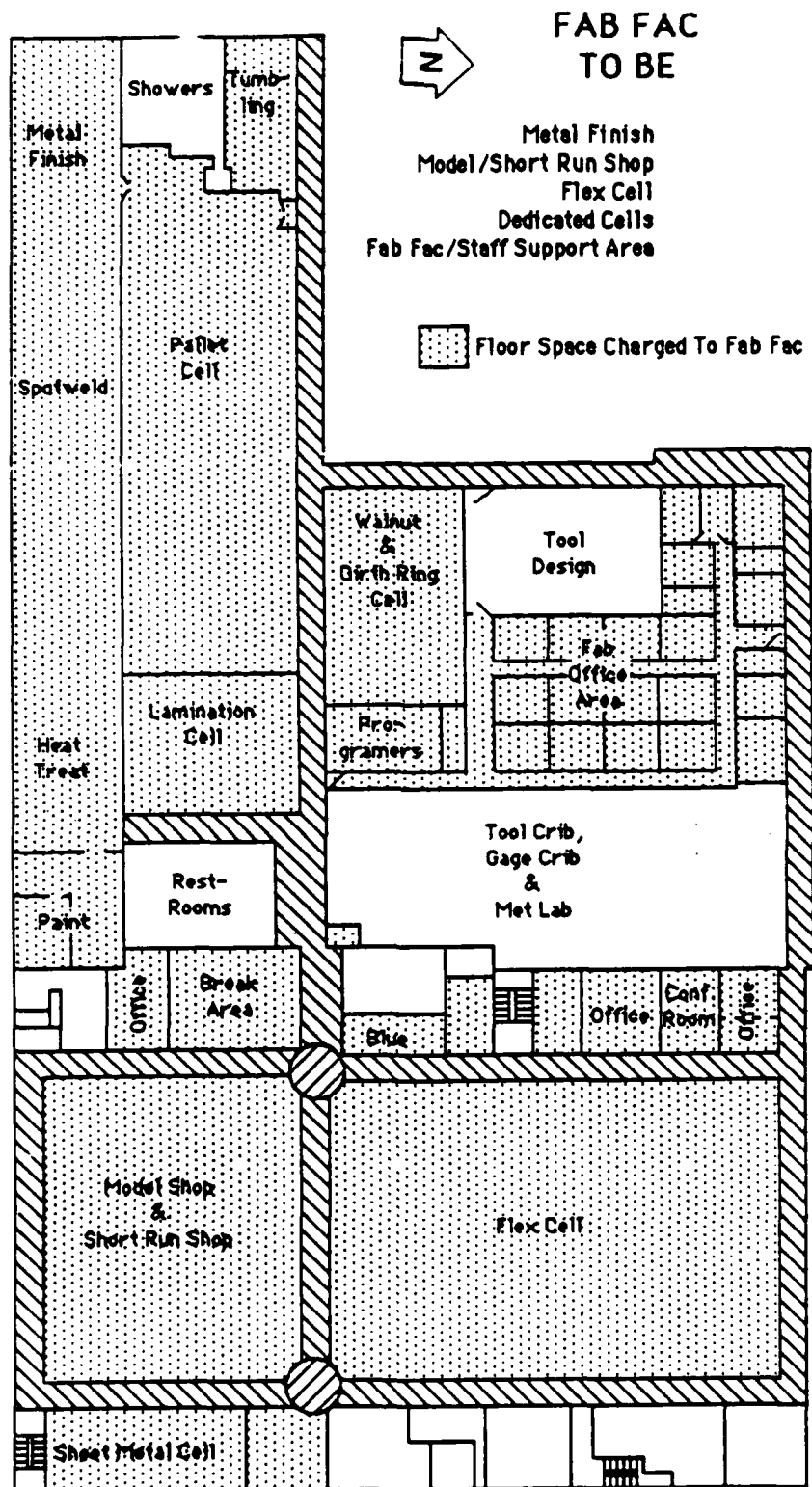
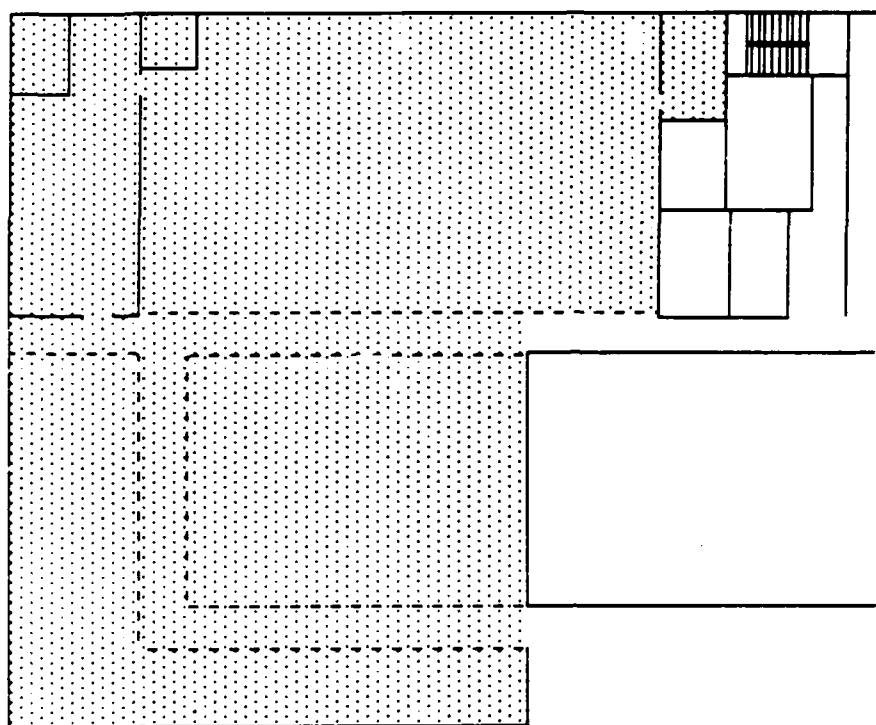


Figure 5.2 "To-Be" Fabrication Facility Floor Space Layout

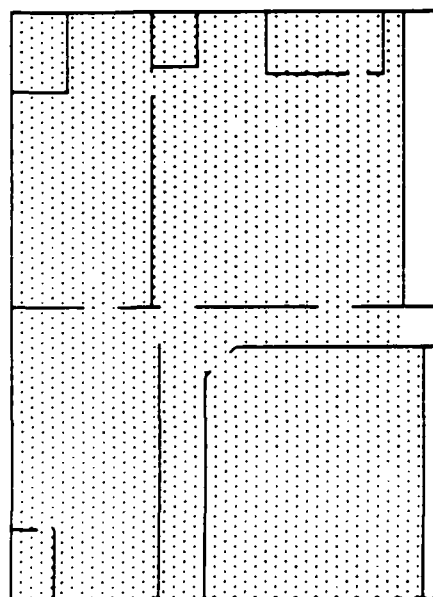


**ST. LOUIS PARK  
TOOL ROOM -- AS IS**

Machine Area 7,800 sq. ft.

Tool Crib 2,000 sq. ft.

-----  
Total 9,800 sq. ft.



**ST. LOUIS PARK  
TOOL ROOM -- TO BE**

Machine Area 4,320 sq. ft.

Tool Crib 1,000 sq. ft.

-----  
Total 5,320 sq. ft.

Figure 5.3 "To-Be" St. Louis Park Tool Room Layout

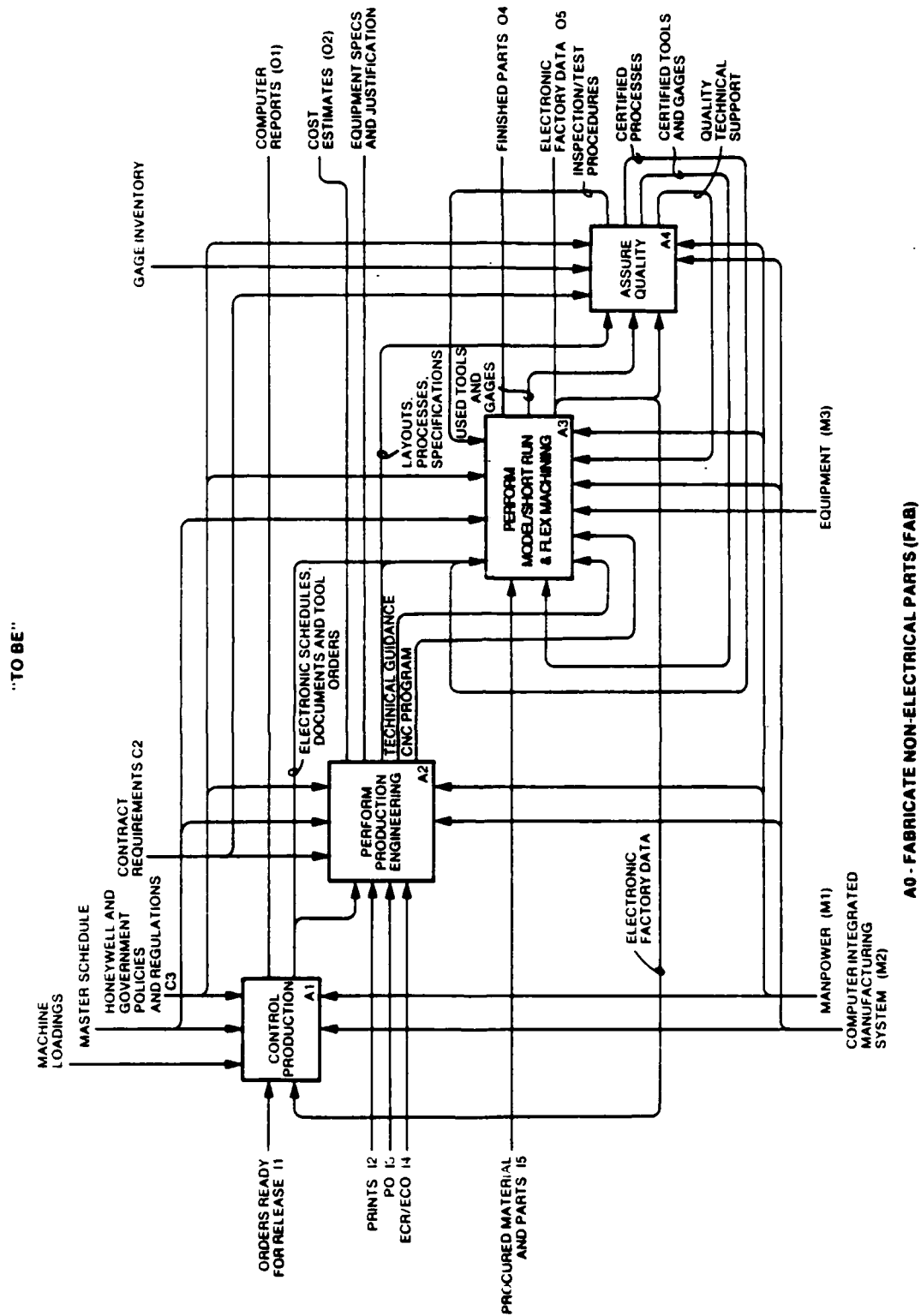


Figure 5.4 "To-Be" Model/Short Run/Flex Shop Workflow Diagram

## MODEL SHOP/SHORT RUN SHOP

The St. Louis Park (SLP) Tool Room is an extension of the Model/Short Run Shop at Stinson/Ridgway (S/R). They are controlled as a single administrative area. Work is frequently shifted for purpose of machine or manpower utilization. It is no longer a "traditional" tool room. There is extensive use of CNC, semi-automatic, and automatic equipment. All sheetmetal work supporting Test Systems and Logistics Operations, Commercial Aviation Division (CAvD), and non-emergency work for the SLP business groups has been transferred to the Stinson/Ridgway Model/Short Run Shop. This represents approximately 40% of the workload by hours. Equipment, other than required for the SLP support mission, has either been transferred to Stinson/Ridgway or surplused.

The Stinson/Ridgway Model Shop/Tool Room is now the Model/Short Run Shop. It plans, schedules and uses the resources of the SLP Tool Room as a direct extension. It serves as an overload area for the Flexible Machining Area. Structured orders (jobs which have a production process and have an alternate routing sheet for Tool Room) are scheduled by the HMS Capacity Requirements Planning (CRP) system. These jobs usually have a set-up time that would exceed run time in terms of actual hours expended on the job. Production Engineers work with the Tool/Model/Short Run Shop on new low volume parts that have volume or profit potential. Allowance for the reserve capacity to meet emergency and unplanned customer needs is maintained by work center constraints and the CRP module of HMS.

If machine capacity is available, moderate run jobs from the Flexible Machining Area are run on Tool Room machines (at either S/R or SLP) to meet utilization requirements. Processes are documented by PE's to allow spare or emergency builds of higher volume parts to be run on compatible Short Run Shop machines. For these transfer jobs, dedicated fixtures are built for specialized repetitive and long-run applications. Fixtures fit on qualified vice collet or general purpose tool plates on machines to reduce set-up time. NC programs and tooling are certified to reduce inspection time. Fixture mounting patterns are standardized for all like or fixture sharing machines to allow flexibility in Fab's wide machine selection. NC programming remains a shared function with PE's and hourly Toolmakers. All NC programmers, both hourly and engineering, report directly to the PE supervisor. Scheduling of programming jobs to meet immediate production shop needs and HMS priorities is a PE responsibility. PE's act as trainer and technical resource for NC programming, new factory equipment and systems.

New models, piece parts, tools and unique applications are broken down into components, processed and entered on the HMS system. The new process derives a primary benefit by use of the Manufacturing Data Control (MDC) and CRP modules of HMS. This "To-Be" job processing and release to the shop floor is shown schematically in Figure 5.5 and described below.

All new or unstructured job requests are roughly broken down by Production Control. They are routed by input to the MDC module and planned by CRP. All phases of pre-production release such as tool design material order placement, stocked material requirements, temporary tool build, numerical control programming, originator estimated completion cost/hours, rough cut loads by manufacturing resource and inputs or approvals by reviewing departments are planned and scheduled via HMS modules. Materials and support are then scheduled to be provided in the proper build sequence. The HMS order is sent to the shop group leader.

# **JOB PROCESSING (MODEL SHOPS) TO BE**

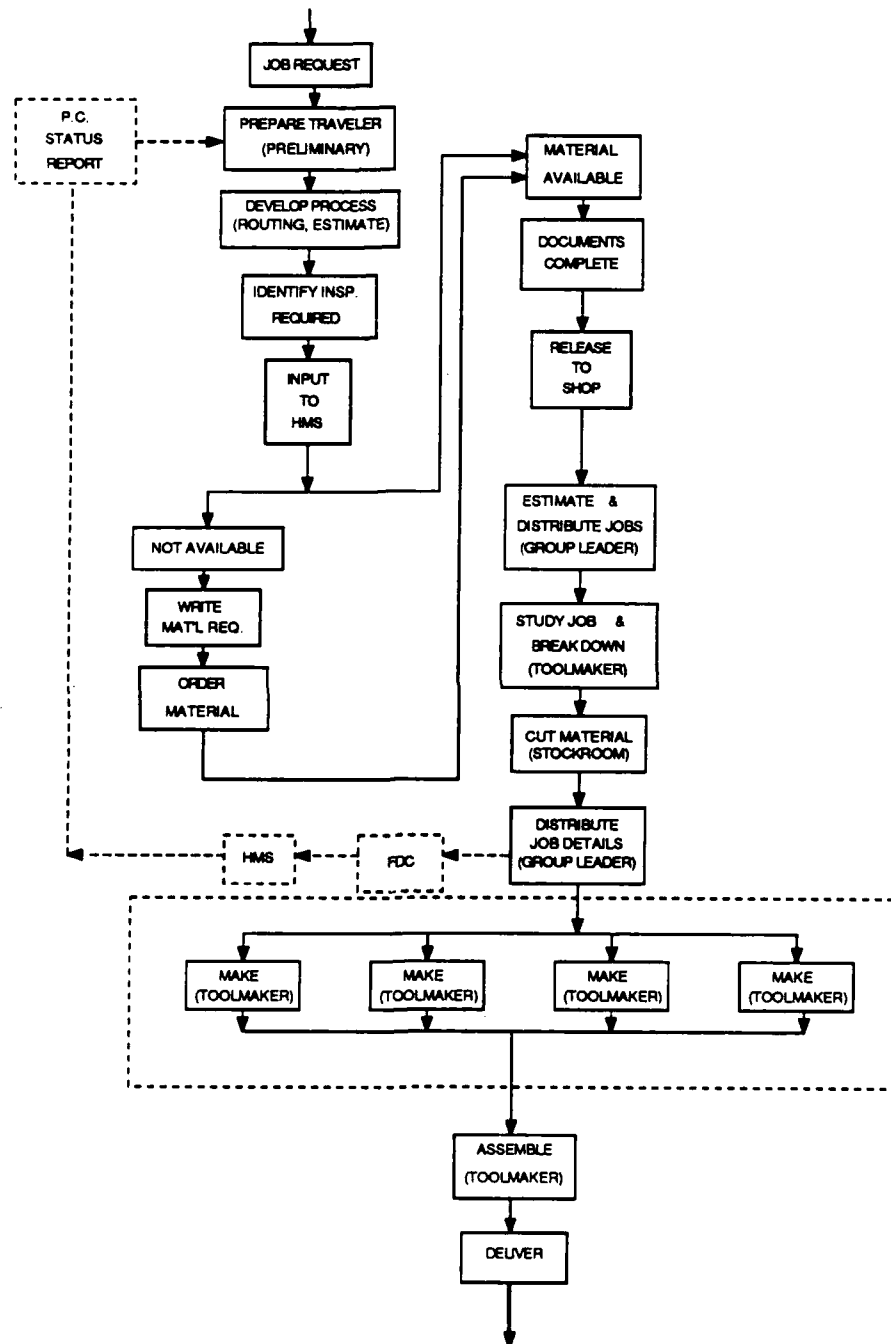


Figure 5.5 "To-Be" Model Shop Job Processing

The group leader reviews the job and assigns it to a Toolmaker Specialist for build breakdown. The specialist breaks the job by TM detail and rough operational components. Operations are estimated for material preparation, Fab wide work center usage and department machines.

The HMS order is amended by Production Control. Notification for planned (due to job analysis) cost deviations from originator estimates are given, and amendments to the TM sought. The group leader then distributes the job per HMS instructions. A single Toolmaker still has overall responsibility for a complete job. Operations to complete segments of a job are assigned to specialist areas within the Tool Room, or specific manufacturing resource in the Fab Facility. Tools, raw material, NC programs and instructions for desired result are prepared for and delivered to the work area to decrease non-recurring costs.

Components of the HMS order are completed simultaneously by multiple Toolmakers working on assigned machines, not complete jobs. For complex component details, temporary holding fixtures, rough process documentation and machine programs have been prepared by other Toolmaker specialists. Factory Data Collection (FDC) is used by HMS to feed back status of the order. Rework or unplanned operations are amended to the MDC module to update delivery projections. As portions of the job are completed, they are scheduled to be assembled, inspected or tested, record retention requirements met, order closed and the product delivered. Delivery projections and order status are available to all Honeywell business groups or HMS inquiry terminals in their area.

The layout of the shops in Stinson/Ridgway and St. Louis Park are displayed in Figures 5.6 and 5.7. Modular arrangements of work surfaces with attached tool cabinets replace bulky wooden desks. The new maple laminated work area clusters may be used by up to four Toolmakers or rearranged for a specific large job. Personal and provided tools, stored in personal toolboxes, are transported on a rolling cart/work surfaces assigned to each Toolmaker. Equipment with low utilization has been surplused. Specialized equipment is no longer duplicated in separate departments but is shared. The combined areas have twelve CNC machines. The Stinson/Ridgway area has three CNC lathes (two styles), two vertical machining centers, a multi-axis CNC wire EDM and a CNC tool grinder. The SLP area has three CNC and one NC machining centers. Most CNC machines have interactive eight color graphic controls, standard tool libraries, the latest advanced features available, DNC connections and direct compatibility with programs of lower featured controls on like machines used in other Fab production areas. Other industry standard Tool Room/precision machines are provided to complement the automated equipment. Toolmakers are trained on all equipment, specialized on some and rotated by assignment to retain competence in the complete scope of their jobs. Capacity in manual equipment and personnel are available to respond to "walk-in" emergency and production support work.

Machine resources are shared with the Flexible Machining Area on a routine basis. Other manufacturing resources are shared with all Fab Fac areas as directed by the HMS routings or special arrangements between supervisors.

**MODEL SHOP/SHORT RUN SHOP**  
**STINSON/ RIDGWAY TO BE**

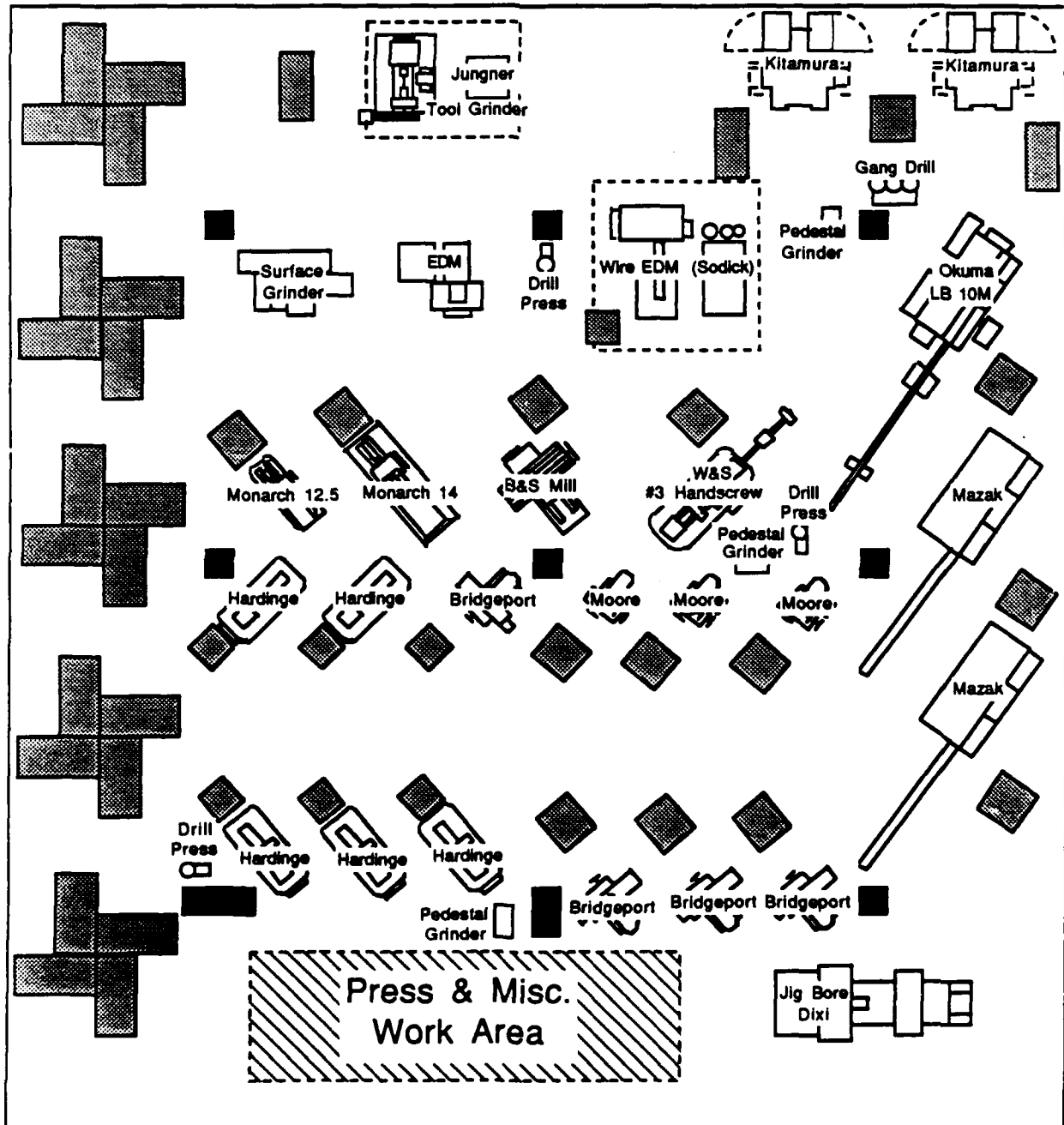


Figure 5.6 "To-Be" Stinson/Ridgway Model Shop/Short Run Shop



# ST. LOUIS PARK TOOL ROOM LAYOUT TO BE

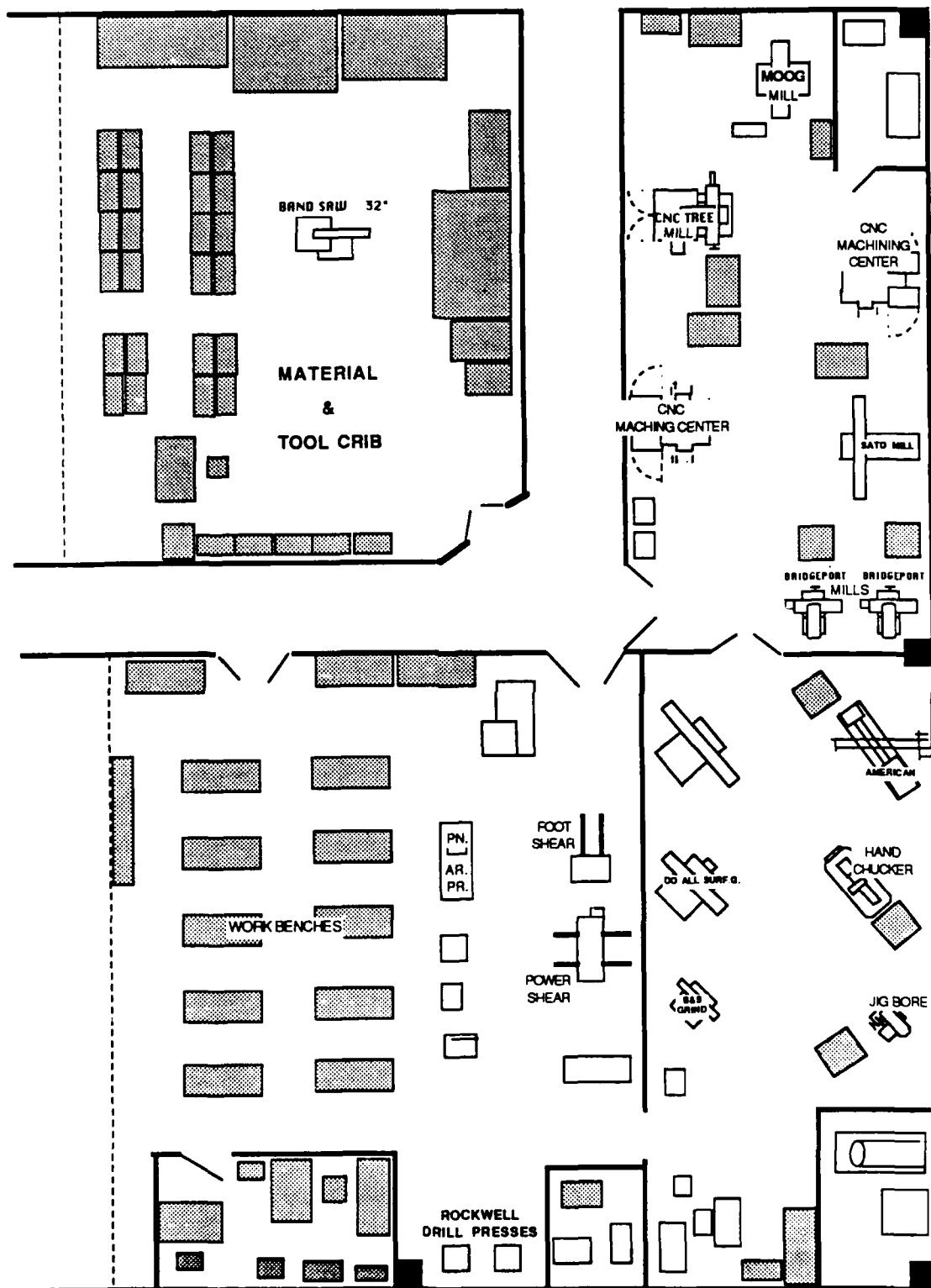


Figure 5.7 "To-Be" St. Louis Park Model Shop

## FLEXIBLE MACHINING AREA

Both moderate and high volume parts that do not pass machine utilization thresholds as cells are produced in the Flexible Machining Area (Flex Shop). Although there is high variety in the processes, parts follow a predictable path through critical manufacturing resources. Part orders are issued with predictable regularity. Engineering and Production Control frequently review the parts population for planned transition for new or revised dedicated work cells or to construct alternate Short Run Shop manufacturing processes.

The Shop Supervisor is responsible for overall cost, quality and delivery of parts manufactured in the area. Processes that must be completed by outside resources are monitored closely. The Shop Supervisor and assigned Production Control person schedule and monitor the area with HMS and associated control/feedback systems discussed in the MIS section of this report.

The Sheetmetal Cell is part of the Flex Shop, but is not discussed here. Due to the specialized nature of the Sheetmetal Cell, it is fully discussed in an individual segment of this final report. The Flexible Machining Area (except the Sheetmetal Cell) is illustrated in Figure 5.8, and discussed below.

The area (Reference Figure 5.8) contains eleven CNC machines supported by automatic, semi-automatic and manual machine tools capable of fully completing machining requirements of parts processed to the area. The major CNC machine tools are: three vertical machining centers with three axis control; one vertical machining center with 3 1/2" axis control; one vertical machining center with four axis control; one CNC lathe with live tools and a bar feed; one CNC lathe with live tools and a chuck; one twin turret, four axis CNC lathe with bar feed; one "swiss" style CNC lathe; one two axis CNC wire EDM machine; and a two axis CNC O.D. grinder. These machines may be operated independently or as "process lines". The process lines are: turning; turning/grinding; milling/drilling; "dither spring" (one part family); 1 1/2" family parts; manual grind area; and the miscellaneous mixture.

Material flow within the Flex Shop, due to the small nature of the parts, will be by hand carry, carts, and pallet movers. Stores hourly personnel will move parts to and from area by existing manual means. The internal movement of parts in the area will be by operator or group leader.

# FLEX SHOP LAYOUT TO BE

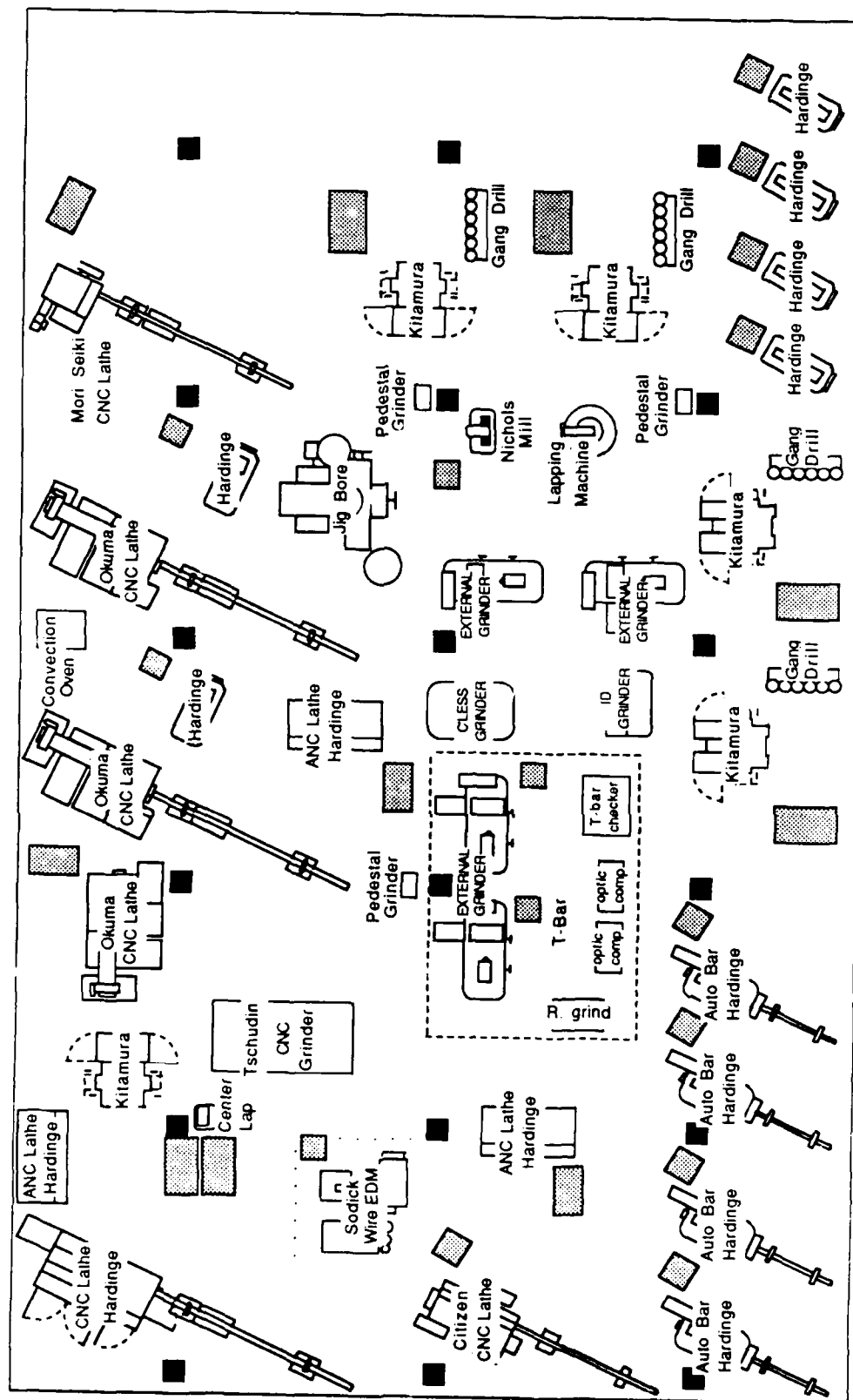


Figure 5.8 "To-Be" Flex Shop Layout

Figure 5.8 "TO-BE" Flex Shop Layout

## SECTION 6

### PROJECT ASSUMPTIONS

The following assumptions have been incorporated into the development and implementation plan for the project. Deviations from the assumptions could have an impact on the projects schedule, cost or savings.

The project assumptions for the Fabrication Facility in general are covered in Section 6 of the Project Overview and are required to implement this project segment. Additional assumptions are:

- A Production Engineer will be available and assigned to the Model/Short Run Shop per the implementation plan in Section 15.
- Floor space requirements in the "To-Be" layout will be available to match timing of the implementation schedule.
- The ten week sample of Tool Room work accurately represents approximate overall annualized future requirements.
- If market projections are low, certain "process lines" in the Flexible Machining Area may have enough volume to become work cells. To provide for this, approximately 3,000 square feet of floor space vacated in the "To-Be" layout fringe areas may be converted from temporary stock storage areas to cell locations. This temporary space will remain available through 1990.

## SECTION 7

### GROUP TECHNOLOGY CODING SYSTEM ANALYSIS

The application of group technology as an analysis tool was of limited use in Project 44. There is no meaningful numbering system, except "tab" numbers, that describes like process characteristics in the approximate 10,640 summaries (routings) that comprise the potential shop order mixture.

"Tab" parts refers to prints and processes that are tabulated on a single print. Those features that have different dimensions that customize a part to a specific application are tabulated on the print. When parts have been processed, all operations that are common on a series of "tab" parts have a common process detail (work instruction) and summary operation number. The tab system has been used, by some business groups, to define a redesigned replacement part.

The manipulation of the investigative parts matrix (see Section 3 of the Project Overview) made use of the process commonalties of often dissimilar products to develop potential work cell or flexible machining sequences for more detailed analysis.

## SECTION 8

### PRELIMINARY/FINAL DESIGN AND FINDINGS

#### INTRODUCTION

The Model Shops, Short Run Shop and Flex Shop final designs were accomplished by performing the sequential tasks outlined in Section 3 of this report. Engineering teams were formed to evaluate the work cell potential for the T-Bar, 1 1/2" Bar, and Dither Spring family of parts. The project core team undertook the investigation of the Model/Short Run Shop and Flexible Machining Area concepts. The investigative base, for all teams, was the parts list and preliminary design concepts developed by the Project 44 core team. The discussion below describes all project findings and the evolution from preliminary design, consolidation of concepts and the resultant final design. This design evolution is discussed below, both independently and in context of the design assimilation into other project segment investigations.

#### CELL INVESTIGATIONS

- T-BAR CELL

The T-Bar Cell is fully discussed in it's own separate segment of this final report . The result of that analysis was a decision not to implement it as a cell. The parts base and capacity requirements were added to the investigative base of the 1 1/2" Bar Cell for turned parts and the Flex Shop for the dedicated grinding equipment.

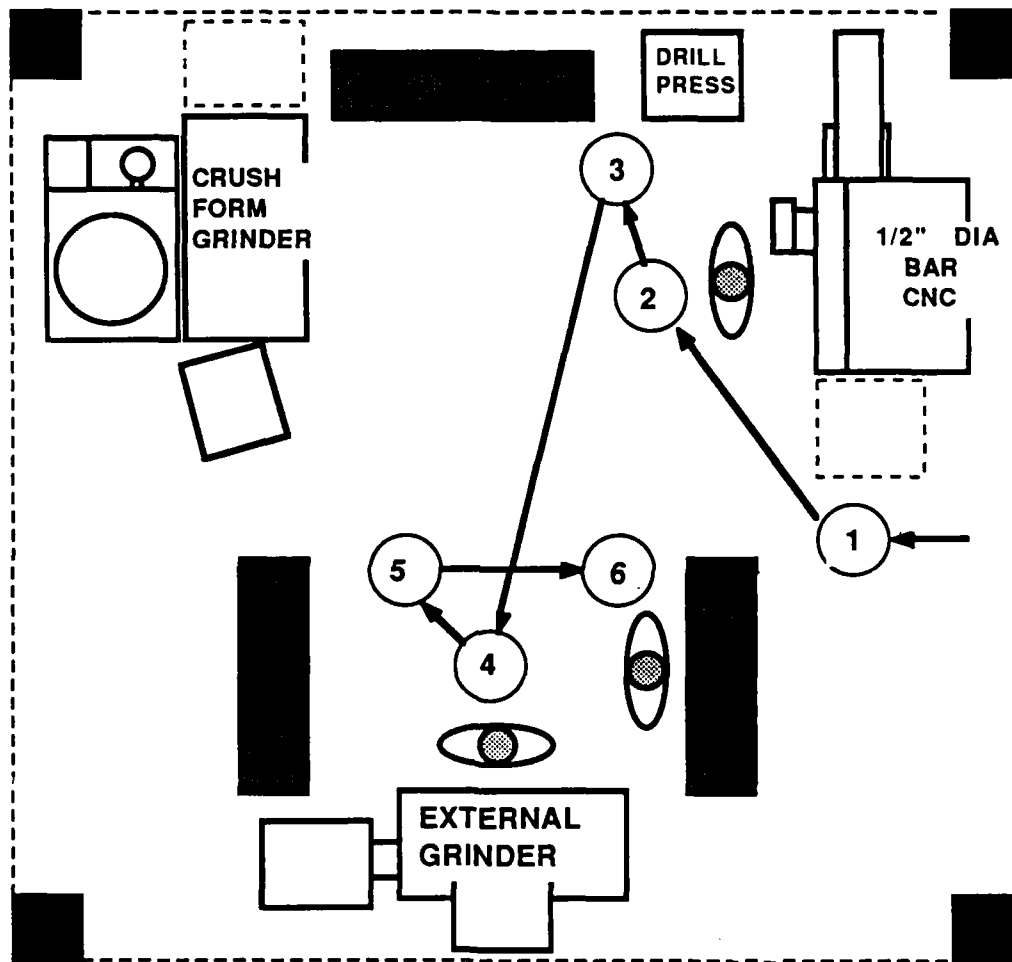
- 1 1/2" BAR CELL

The project core team developed the concept/preliminary design of the 1 1/2" Bar Cell. This type of cell would produce parts that have turning and milling characteristics. With the latest CNC technology, there exists a style of equipment that has the capability to do turning as well as cross axis milling and drilling. This style of equipment became the primary element in the equipment search for the group of parts involved in the T-Bar and 1 1/2" Bar Cells.

The equipment/technology search identified various styles of turning equipment that could produce the parts selected for the T-Bar and the 1 1/2" Bar Cell concepts. The results from this preliminary search identified two pieces of equipment for these dedicated cells. The preliminary concepts for a dedicated T-Bar and 1 1/2" Bar Cell are shown in Figures 8. 1 and 8. 2. The Okuma model LB-10 was selected for the 1 1/2" Bar Cell and the Citizen model F-12 for the T-Bar Cell.

As the analysis progressed, it was found that the parts that could be produced by the 1 1/2" Bar Cell (Okuma LB-10) offered a wide variety of different geometric shapes. With the versatility in the machine, it was decided to interface it with the Flexible Machining Area as the 1 1/2" Bar Cell because it would give us the most utilization from the machine. The 1 1/2" Bar Cell flow path is described below in the Flexible Machining Area heading of this section.

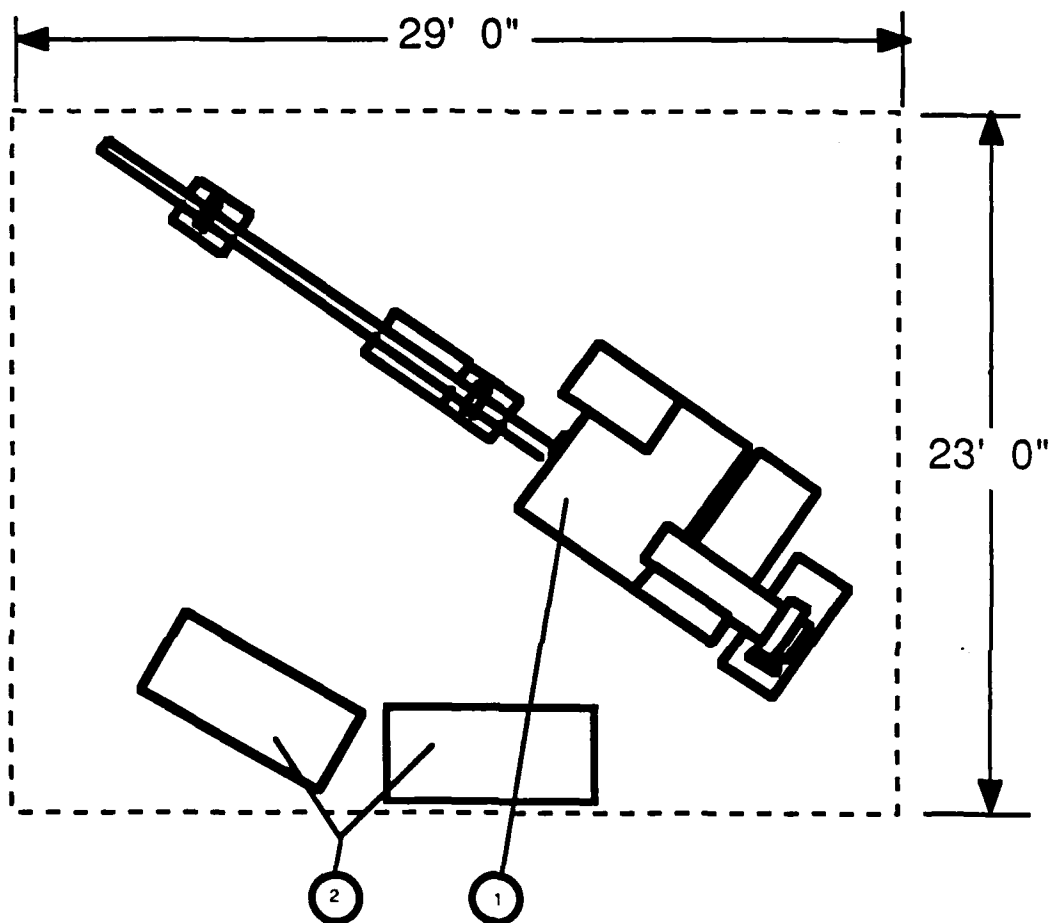
**FLEX SHOP/MODEL SHOP/SHORT RUN CELL**  
**PRELIMINARY DESIGN FOR T-BAR CELL**  
**TORSION BAR CELL (APPROX. 400 SQ FT)**



- |                                   |                        |
|-----------------------------------|------------------------|
| 1. HEAT TREAT (BAR)               | 4. GRIND WIRE DIAMETER |
| 2. MACHINE COMPLETE               | 5. DE-BURR             |
| 3. DRILL .025 DIA. (INTERNAL OP.) | 6. CHECK "K" FACTOR    |

Figure 8.1 Preliminary Design For T-Bar Cell

**FLEX SHOP/MODEL SHOP/SHORTRUN CELL  
PRELIMINARY CONCEPT FOR 1 1/2 DIAMETER BAR CELL**



1. CNC lathe with simultaneous cut-off end machining capability.
2. Deburring

1 1/2 Diameter Bar Turning Cell  
(Approx. 600 Square Feet)

Figure 8.2 Preliminary Concept For 1 1/2" Bar Cell



The parts selected for the T-Bar Cell configuration did not have enough volume to utilize the equipment to the fullest and obtain a good return on the investment. At that time, a decision was made to also include the T-Bar Cell configuration into the flexible machining environment.

- DITHER SPRING CELL

The Dither Spring is an integral part of the Ring Laser Gyro's (RLG) GG1342 package. It is a round part, approximately 1.8 inches in diameter, 1 inch long with a clover leaf configuration cut out about its center line axis. This high nickel based invar part is gummy, hard and difficult to machine on a lathe with consistent tool life. As a result, the Dither Spring is best machined from raw material slugs versus bar feeding.

#### As-Is Process

To clarify the design concept developed by the project core team the "As-Is" conditions for the specific dither spring part are discussed below. The current "As-Is" Dither Spring process is listed sequentially in Figure 8.3 and is shown as the comparison base to derive the "To-Be" dither spring process. Focussing attention to the current Dither Spring process shown in Figure 8.4, raw material is delivered to the turning department in 2 inch diameter X 1.2 inches long slugs. The Invar part is rough turned to a .050 inch oversize condition for the removal of laps and inclusions. Stores personnel transport by pallet, lot sizes of 500 parts to the Metal Finish Department, where the parts are degreased in preparation for subcontract stress relieving.

After subcontract heat treatment, the dither springs are returned to turning where material is removed to a pre-grinding oversize condition. At this point, the 500 parts are moved to the NC Milling department for drilling of wire Electrical Discharge Machining (EDM) pilot and mounting holes. Without wire EDM capabilities in-house, the outside diameter and face is ground for subcontract preparation in the Grinding Department. The subcontractor receives the dither springs and wire EDMs the clover leaf configuration about its centerline axis. The parts are inspected in-house and shipped to the Grinding Department, where final O.D. and perpendicular dimensions are held. Next, part identification numbers are stamped and wire EDMed edges are hand deburred by the miscellaneous machining department. Metal Finish degreases the dither springs in preparation for the final stabilization heat treatment. The parts are complete after a vapor honing operation is performed. This inefficient manufacturing process takes an average of 404 calendar days to complete.

#### Preliminary Design Concept

Based on the machining requirement and projected marketing volumes, a core team of three Production Engineers developed the preliminary Dither Spring Cell. The objectives of the cell is to allow an efficient, cost effective manufacture of dither springs by bringing wire EDM and heat treatment in-house, reducing standard hours, and shortening lead times. The initial concept was derived by the use of three machine tools. First, the CNC Okuma lathe (LB10-M) with live tooling was chosen for its ability to do the pre-grind turning and drilling for wire EDM pilot and mounting holes.

### DITHER SPRING PROCESS FLOW COMPARISON

OPERATION DISCRIPTION	AS-IS PROCESS	PRELIMINARY	TO-BE PROCESS
Cut slugs in stock room-----	X	X	X
Inhouse stress relieve-----		X	X
Rough turn-----	X		
Degrease-----	X		
Subcontract stress relieve-----	X		
Face and turn one half-----	X	X	internal
Face and turn complete-----	X	X	internal
Drill complete-----	X	X	X
Lap centers-----	X	internal	internal
Grind O.D.-----	X		
Grind end perpendicular-----	X		
Subcontract wire EDM-----	X		
Inhouse wire EDM-----		X	X
Lap centers-----	X		
Grind O.D.-----	X		
Grind end perpendicular-----	X		
Grind complete-----		internal	internal
Deburr wire EDM webs (two ends)----	X	internal	internal
Stamp identification number-----	X	internal	internal
Degrease for heat treat-----	X	X	X
Stabilize-----	X	X	X
Vapor hone by wet blast-----	X	X	X

Figure 8.3 Dither Spring Process Flow Comparison

# PRELIMINARY DITHER SPRING CELL LAYOUT AND WORK FLOW DIAGRAM

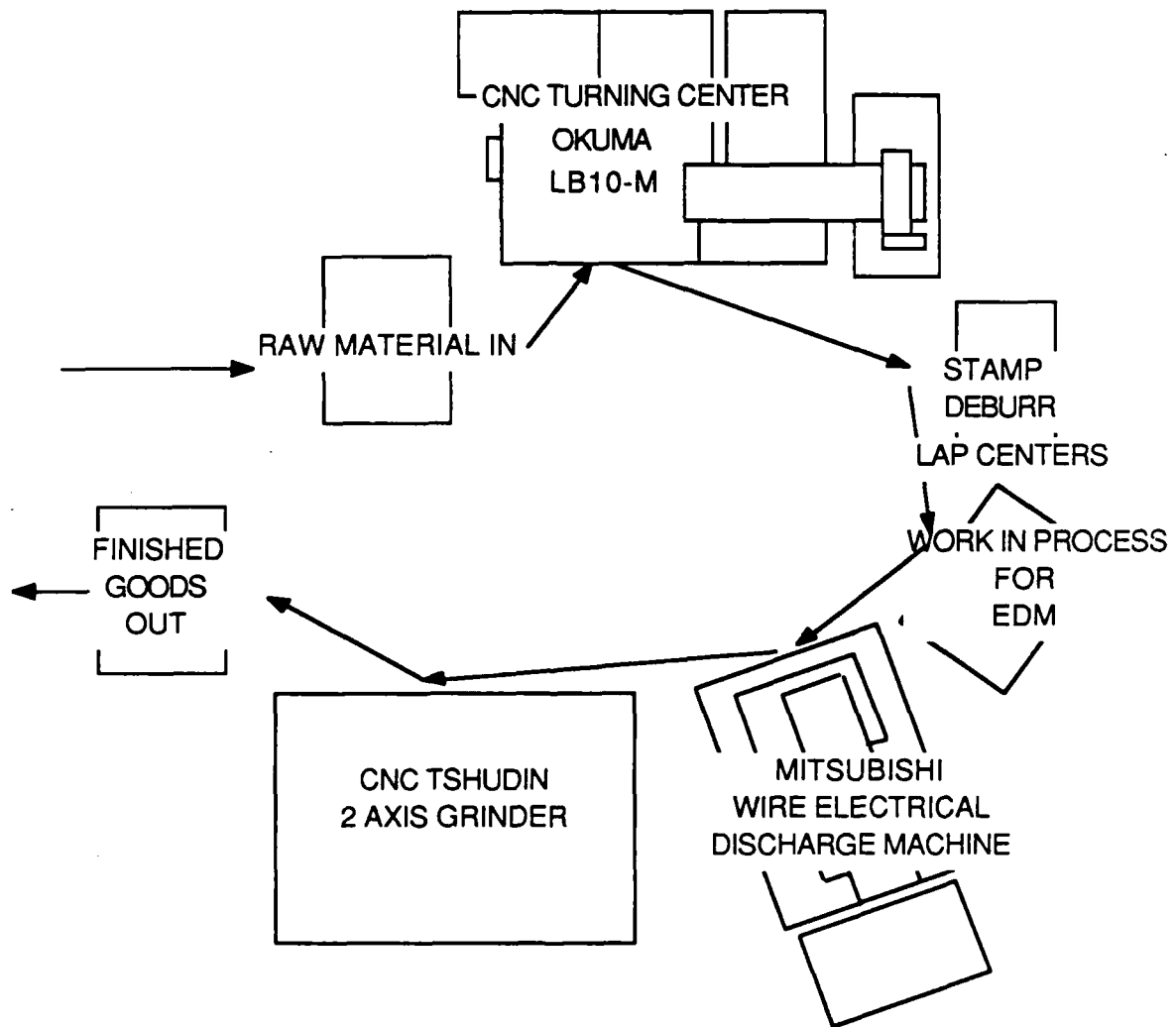


Figure 8.4 Preliminary Dither Spring Cell and Material Flow

Second, a five axis Mitsubishi Wire EDM was added to machine the clover leaf configuration to the center line of the part. Third, a two axis CNC Tshudin grinder was introduced for high precision grinding of diameters and shoulders. Arrangement of these machines in a cellular design resulted in the preliminary Dither Spring Cell which is shown in Figure 8.4.

Focussing attention to both Figures 8.3 and 8.4, raw material dither spring slugs are cut, and stress relieved prior to machining. The heat treatment will be completed in-house within a hydrogen atmosphere to control oxidation. Stress relieved raw material will be delivered to the Dither Spring Cell and buffered adjacent to the CNC lathe. Complete turning and drilling of the parts will be accomplished in the Okuma lathe in one operation.

Within the cycle time of the lathe, the operator will stamp, deburr and lap centers in preparation for wire EDMing and CNC grinding. Parts are then buffered at the wire EDM. The five axis wire EDM, with automatic wire feed, will burn parts for 24 hours unattended. Final O.D. and face grinding will be internal to the CNC lathe. At this point, dither spring parts are machined complete and buffered in finish goods out. Lot sizes of 100 will leave the Dither Spring Cell for efficient post machining processing.

In this cell, the wire EDM is the bottleneck in the line flow operation, two machines are required to operate the cell efficiently. As a result, 2-3 week manufacturing lead times will be achieved. By manning the EDM machining cell with one operator, responsibility of quality will be controlled within one group.

The preliminary Dither Spring Cell concept was abandoned do to the under utilization of the CNC two axis grinder and CNC lathe. To better utilize these machines, a new "process line" approach was developed into a final design. The Dither Spring process flow path is described in the Flexible Machining Area portion of this section.

## FLEXIBLE MACHINING AREA

An engineering team was formed to evaluate the Flexible Machining Area (Flex Shop) concept developed by the core engineering team. The original parts base for this segment was the original high volume list of parts (as described in Section 3 of the Project Overview) less those parts that were being evaluated for work cell potential.

This modified parts base was again sorted by computer manipulation to identify flow paths. The work loads fell into four primary paths: turn, mill/drill, turn/mill/drill, and turn/grind. Examination of the processes for the individual parts indicated that there was not a great potential for savings by reprocessing to CNC equipment. Most of the parts had been recently converted (within the last two years) to newer existing Fab Fac NC or semi-automatic machines. Delivery and product quality control were thought to be the primary benefits of processing these moderate volume parts sequentially in a single responsible area.

During weekly meetings with other project teams, it was discovered that the process paths were also common in many of the high volume parts being considered for work cells. The lack of sufficient volume to fully utilize/justify proposed cells was also realized. A project consensus was reached in a decision to merge the parts from the 1 1/2" Bar, 1/2" (from the T-Bar) and

Dither Spring Cell proposals into the Flex Shop evaluation. The load hours of these respective hours were added to the parts matrix and the matrix was again manipulated for process flow paths trends.

Weekly meetings with all team leaders uncovered a gap between perceived need and economic justification for some of the Model/Short Run Shop equipment and the Flex Shop process line requirements. It was decided to merge the capital needs of the two areas. Many of the lower volume parts in the Short Run Shop parts base were found to have significant potential for reduced manufacturing costs if the available capacity from the proposed process lines could be utilized for them. The adjusted hours base (as described in the Model Shop section of this report) was merged with the Flex Shop load hours to provide an overall capacity baseline for the combined shops. Capital equipment was selected, as described in Section 11, to meet overall capacities. The equipment selected was divided into three types, dedicated Model/Short Run Shop, dedicated Flex Shop and equipment shared between the two areas.

Equipment, process flow paths and the Model Short Run Shop requirements were arranged using a variety of methods. Analysis by load hours, visual flow paths (by use of traditional "cut and paste" models) and computer generated layouts were used to develop the final design. All final designs were simulated by area/equipment manipulation.

Final manipulation of the parts matrix against the "To-Be" processed parts resulted in six process flow paths. The paths are: turning path, turning/grinding path, milling/drilling path, 1 1/2" Bar path, grinding path and the Dither Spring process flow path. The overall area layout is shown in Figure 8.5. The group of parts designed for this area are done complete and removed from the area to the stockroom. The individual process flow area's are illustrated in separate figures and discussed below.

- TURNING PATH

Involves a group of parts where only turning operations are required. Figure 8.6 highlights the group of equipment dedicated to this path.

- TURNING, GRINDING PATH

Some parts require a secondary grinding after turning or heat treat for accuracy requirements. These types of parts will be manufactured in the area highlighted in Figure 8.7. These types of parts are typically done complete and removed from the area to stock.

- MILLING, DRILLING PATH

These parts are fundamentally a group of castings and parts machined from solid stock that require a milling and drilling path. This path is highlighted in Figure 8.8.

- 1 1/2" BAR

As described above in the 1 1/2" Bar investigation, this section of the Flex Shop includes parts that have turning and milling characteristics. Figure 8.9 identifies these areas.

# FLEX SHOP LAYOUT

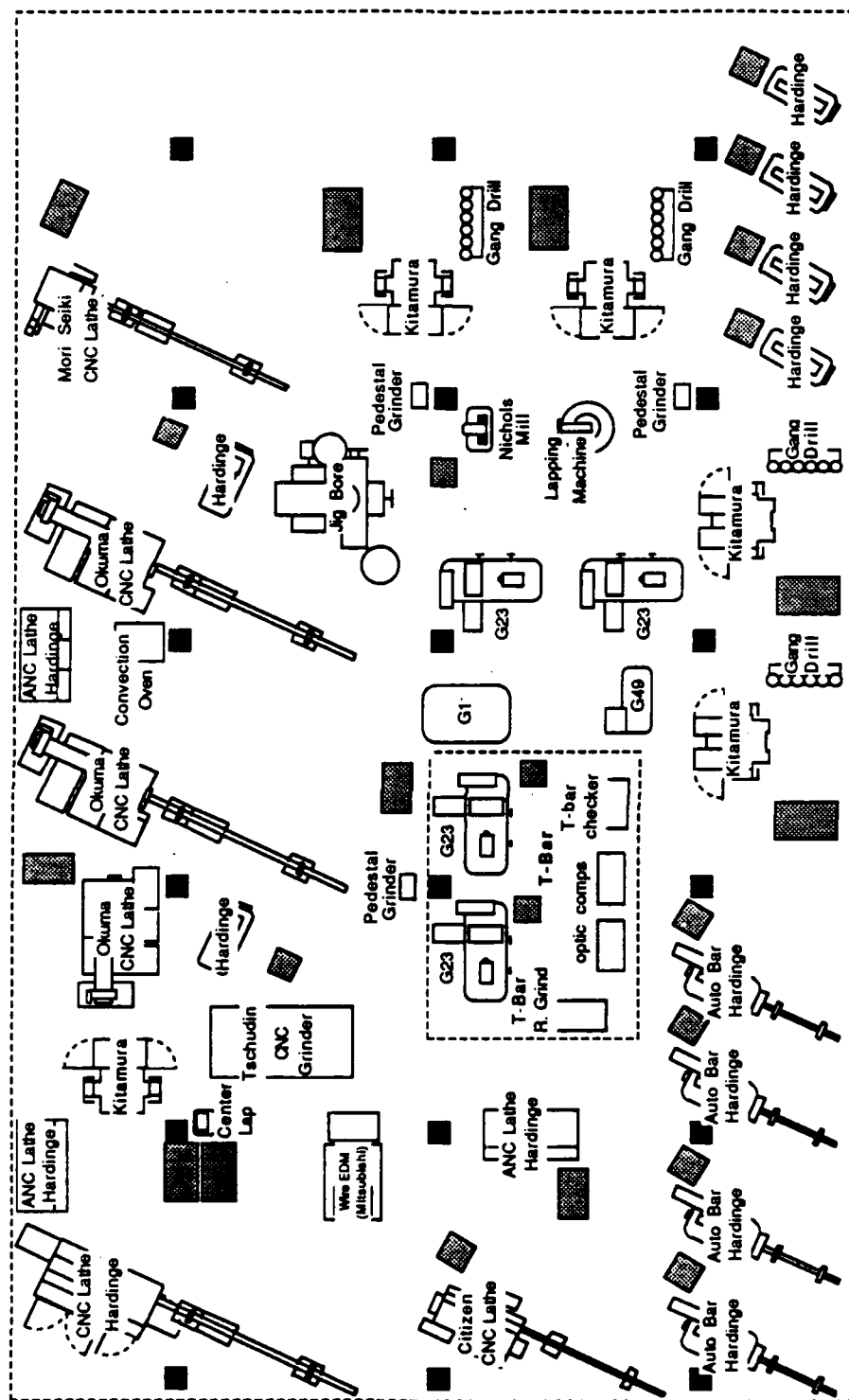


Figure 8.5 "To-Be" Flex Shop Layout

## FLEX SHOP TURNING AREA

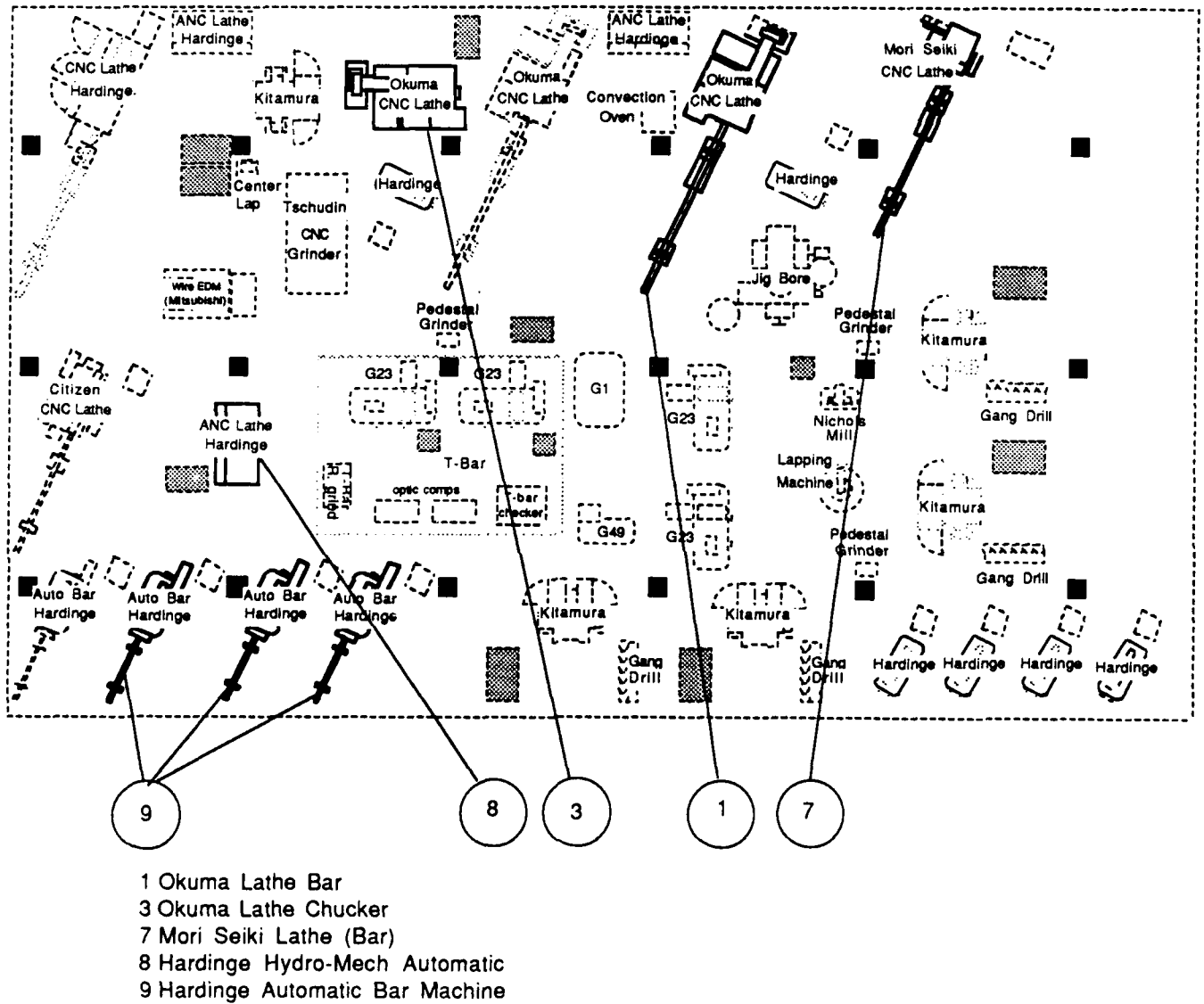


Figure 8.6 Flex Shop Turning Area

# FLEX SHOP TURNING, GRINDING AREA

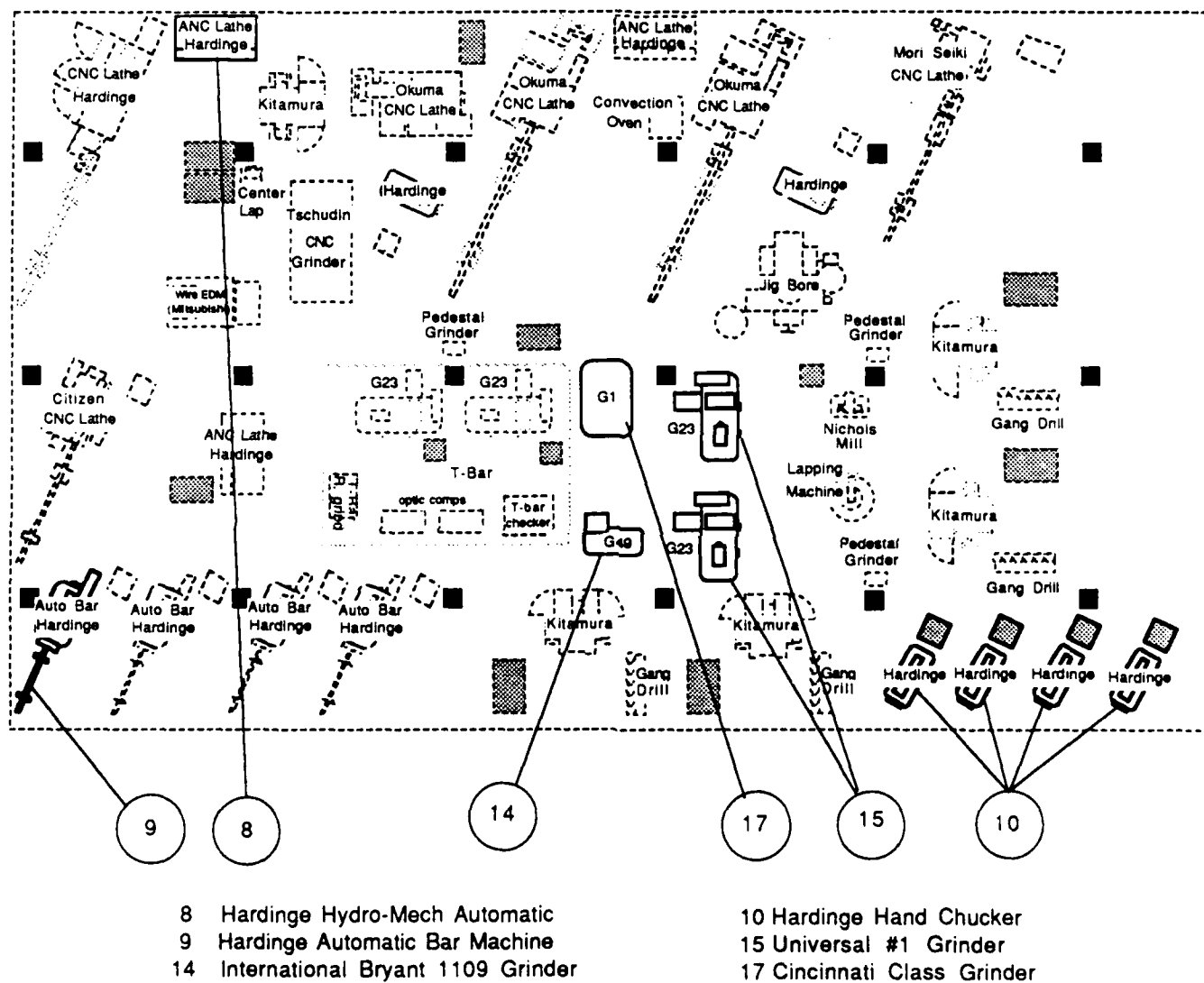


Figure 8.7 Flex Shop Turning, Grinding Area



### FLEX SHOP MILLING, DRILLING AREA

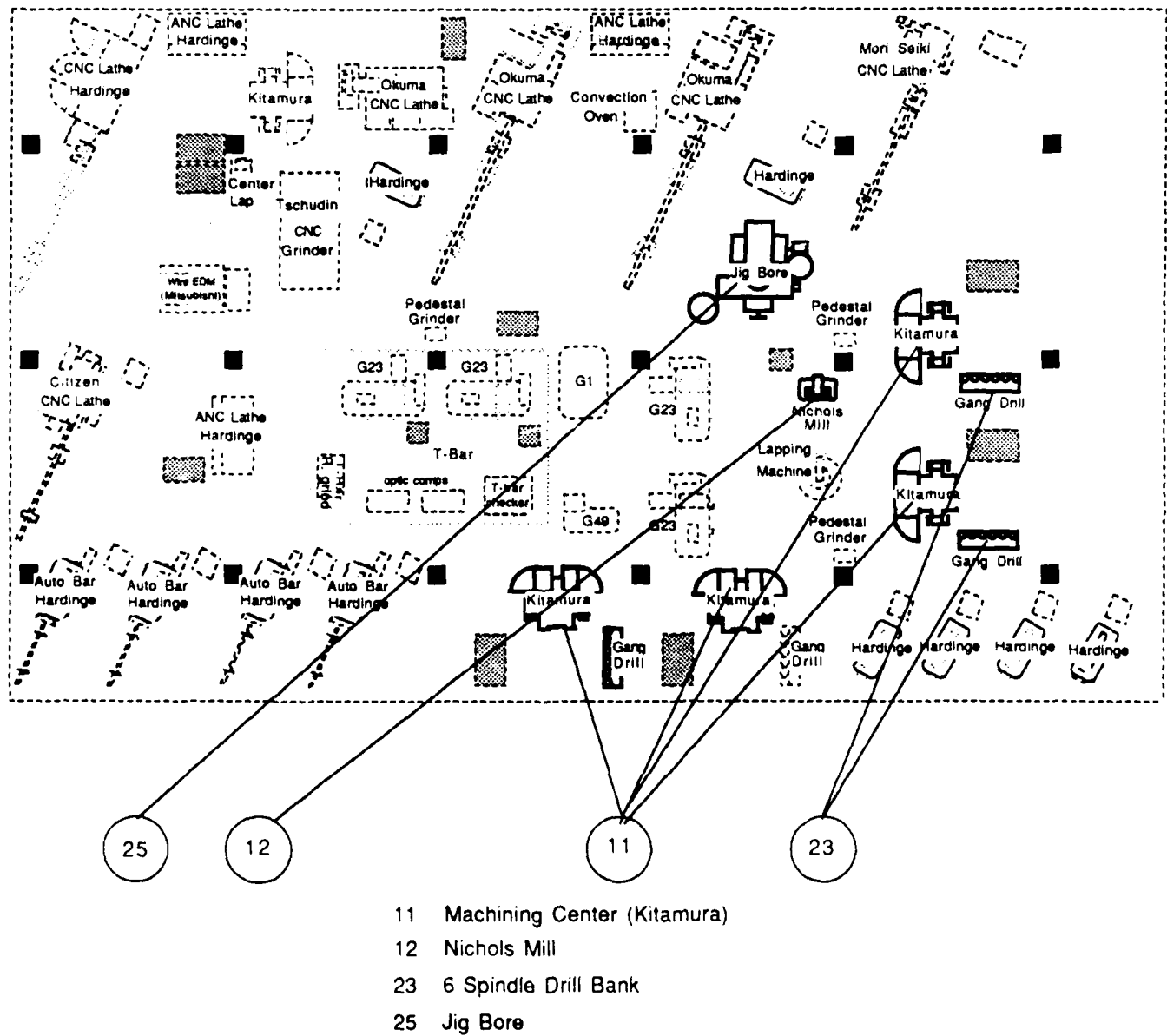
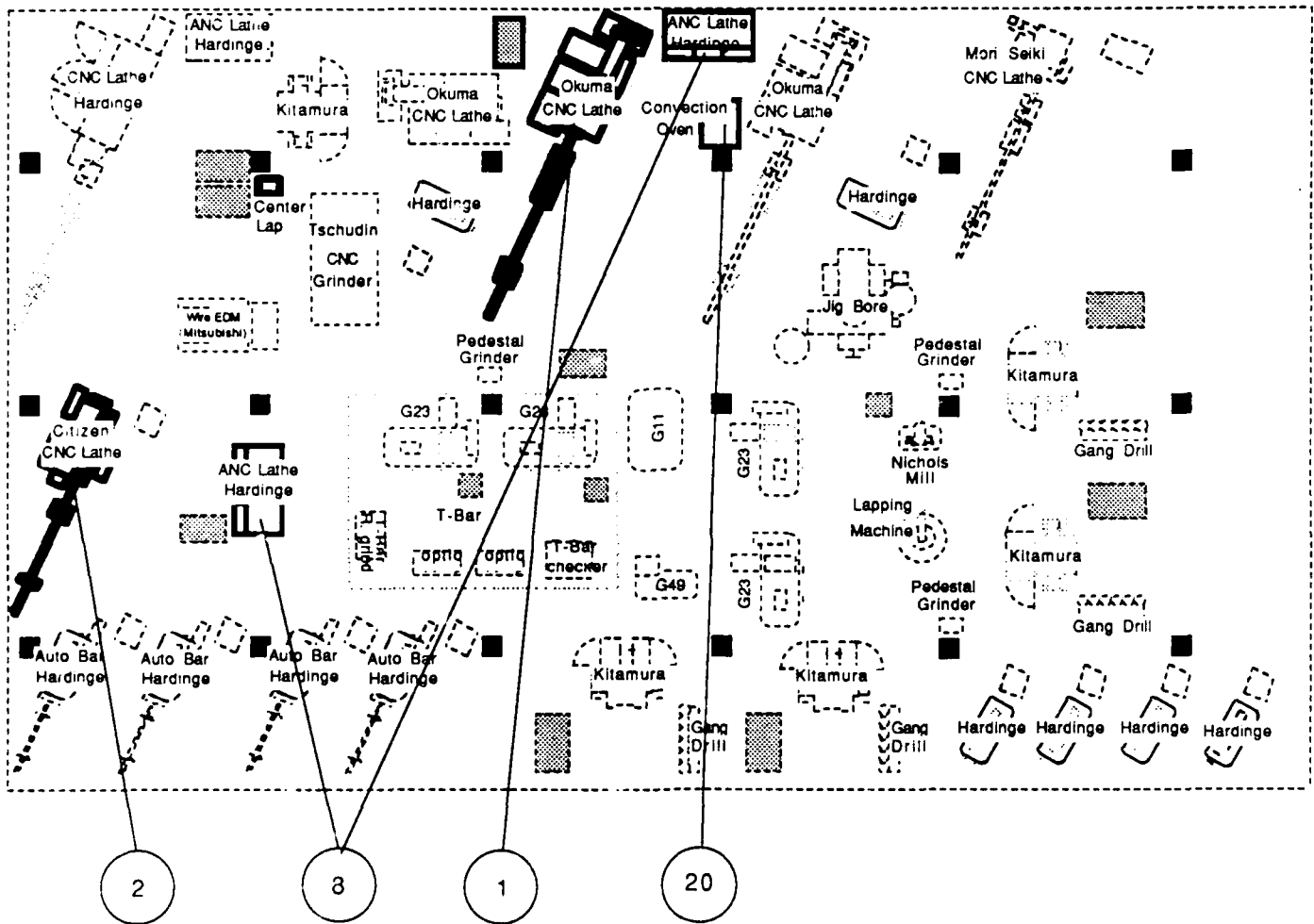


Figure 8.8 Flex Shop Milling, Drilling Area

# FLEX SHOP 1 1/2 INCH BAR CELL AREA



- 1 Okuma CNC Lathe
- 2 Citizen CNC Lathe
- 8 Hardinge AHC Lathe
- 20 Convection Oven

Figure 8.9 Flex Shop 1 1/2 Bar Cell Area

- GRINDING

The Grinding area handles a configuration of parts that have single operational grinding characteristics. This area is tied in with the Flex Shop and is highlighted on Figure 8.7. It includes dedicated support operations to other Flex Shop parts and the dedicated "T-Bar" equipment.

- DITHER SPRING FLOW PATH

To give manufacturing flexibility, a process line flow that incorporated turning, milling, drilling and grinding was developed. This process flow line was designed primarily to produce the dither springs cost effectively by reducing standard manufacturing hours, and shortening lead times. The machines selected to manufacture the dither springs are as follows: (1) CNC turning center; (1) CNC machining center; (1) 5 axis wire EDM and (1) 2 axis CNC grinder.

Dither Spring production will utilize the CNC grinder, lathe, machining center and wire EDM at varying levels. To achieve high asset utilization, the remaining machine capacity will be filled by parts that conform to similar machining flow paths. Referring to the "To-Be" Dither Spring process flow path summarized in Figure 8.3 and the Dither Spring area of Figure 8.11, raw material is cut into slugs, stress relieved and delivered to the dither spring machining area. Raw slugs are turned to an oversize condition in the turning center flagged out by circle #6 (Figure 8.11). This is an internal operation for drilling the wire EDM pilot and mounting holes. This operation is completed in the CNC machining center flagged out by circle #11, which prepares the parts for wire EDM. Parts are buffered on shelving adjacent to the wire EDM machine.

Machining of the clover leaf will be performed unattended in the wire EDM machine flagged out by circle #5. This machine is considered the bottleneck operation and will run 24 hours per day. Excess load will be machined in the Model Shop/Short Run Shop's wire EDM. After EDM, the dither springs are marked for identification, and centers are lapped (circle #22) in preparation for final O.D. and face grinding. The parts are completed in a 2 axis grinder shown by circle #4. This machining area will be attended by two operators; the first for operating the turning and milling centers and the second for operating the wire EDM machines and 2 axis CNC grinder. By operating the machining area in this manner, gained machine flexibility will allow high asset utilization. This will be achieved by loading this area with parts with machining characteristics of turning/milling/drilling and grinding or any combination thereof.

#### MODEL SHOPS AND SHORT RUN SHOP

The Tool Room/Model Shops were found to produce tools, models, and support special projects and some low volume production operation. There was an absence of time standards for all but the planned manufacturing operations. There was no reliable forecast other than historical use patterns by calendar months. The preliminary design concept, developed by the projects core engineering team, was in four parts:

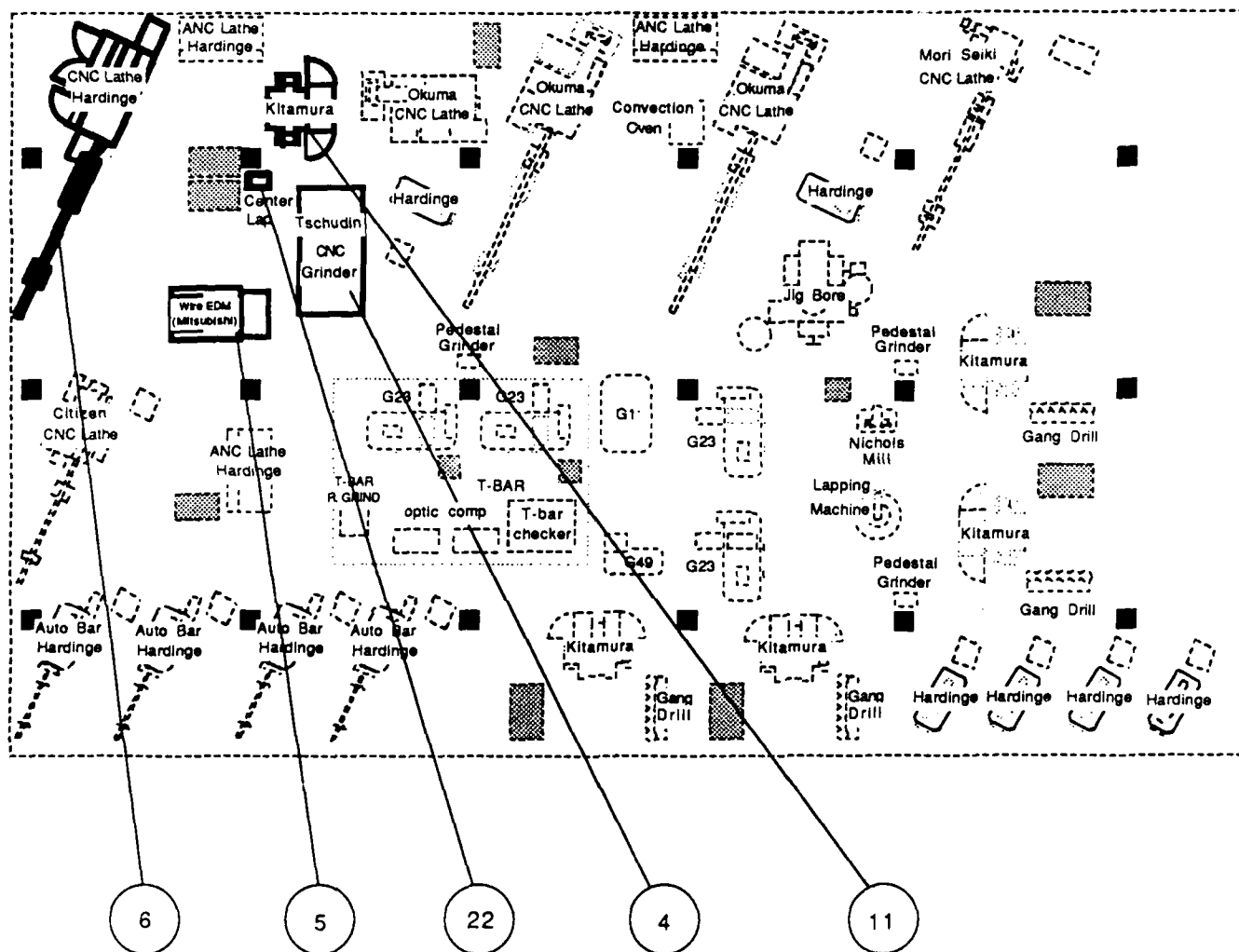
The floor plan of the 1987 International Manufacturing Exposition is a detailed layout of the exhibition hall. It features a variety of machine tool exhibits, including CNC lathes, grinding machines, and drilling equipment. The plan is organized into several main sections, with exhibits arranged in a grid-like fashion. Key areas include:

- Top Left:** Mori Seiki CNC Lathe, Jig Bore, and various grinding machines.
- Top Center:** Kitamura, Gang Drill, and Pedestal Grinder.
- Top Right:** Hardinge, Gang Drill, and Pedestal Grinder.
- Middle Left:** Okuma CNC Lathe, Convection Oven, and Jig Bore.
- Middle Center:** G23, G1, G23, G49, and various grinding machines.
- Middle Right:** Hardinge, Gang Drill, and Pedestal Grinder.
- Bottom Left:** ANC Lathe, Hardinge, and various grinding machines.
- Bottom Center:** T-Bar, R. Grind, T-Bar checker, optic comps, and various grinding machines.
- Bottom Right:** Auto Bar, Hardinge, and various grinding machines.

The plan also includes a legend for different types of exhibits and a scale bar.

24 T-Bar Cell

# FLEX SHOP DITHER SPRING AREA



- 4 Tschudin 2 Axis Grinder
- 5 CNC Wire Cut EDM
- 6 CNC Lathe, 4 Axis Hardinge
- 11 Machining Center Kitamura
- 22 Center Lap

Figure 8.11 Flex Shop Dither Spring Area

- First, eliminate the St. Louis Park Tool Room and combine it with the Stinson/Ridgway Tool Room, without increasing total space allocated to the Stinson/Ridgway Tool Room.
- Second, provide new, multi purpose CNC equipment to replace the "traditional" Toolmaker equipment in both shops.
- Third, change the job process from one person sequentially doing one job to more than one persons completing portions of a job simultaneously (reference Figures 8.12 and 8.13)
- Last, route low volume production orders (where actual set-up would exceed actual run hours) to the Tool Room for single source responsibility for cost, quality and delivery.

The preliminary design concept for this arrangement was labeled the Low Volume High Variety Shop (LV/HV Shop). Meetings were held with senior Fab management, staff and Tool Room supervisors to discuss the concepts and decide upon evaluation/analysis methods. It was decided to develop a form, to be completed by every Toolmaker doing any job, to collect raw use data for analysis. Interviews were conducted with Toolmakers to collect inputs for the form construction. At a Toolmaker team meeting, the preliminary design concepts and proposed data collection forms were presented and discussed.

At the recommendation of the Tool Room team, several changes were made to the collection form to give the Toolmakers a simplified form they could use to describe the task they perform.

The data collection forms were filled out, for all tasks performed by Toolmakers at both building locations, for ten weeks. The forms (reference Figure 8.14) collected: part/tool number; job number; brief task description; number and identification of separate details (components being built); quantity started/completed; job requester hour estimate; group leader adjusted original estimate; machines hours used; number of machine hours a setup was held; Toolmaker/staff opinion on new equipment that would have improved the job; an estimate of hours savings potential with different equipment and Toolmaker identification.

The raw data was entered daily into a matrix. This information was summarized weekly on printouts. The weekly collection of operator comments on the collection forms, the piece part prints or specifications of projects were studied by the project core team.

The summation of the ten weeks data is graphically illustrated in Figure 8.15. The base data was extrapolated to represent annual hours of usage by major machine type. There is a strong suggestion that the hourly spread by equipment type is an accurate projection of a normal distribution. The first six weeks of data collection (rolling actuals) altered the projected total less than 10%. Weeks seven through ten had less than a 5% effect on the annual projections. Most hours recorded indicated potential for improvement of operation costs by replacing manual machines with modern CNC type equipment. Very little of the recorded work was hand, assembly, or bench type tasks. The largest distribution of hours was milling, turning and jig bore. Adding the load from the Tree (2 axis vertical, manual tool change CNC mill) and the Dixie horizontal jig bore directed primary equipment selections strongly towards CNC Tool Room milling machines, with turning equipment next on the equipment investigation list.

# **MODEL SHOP WORKFLOW AS IS**

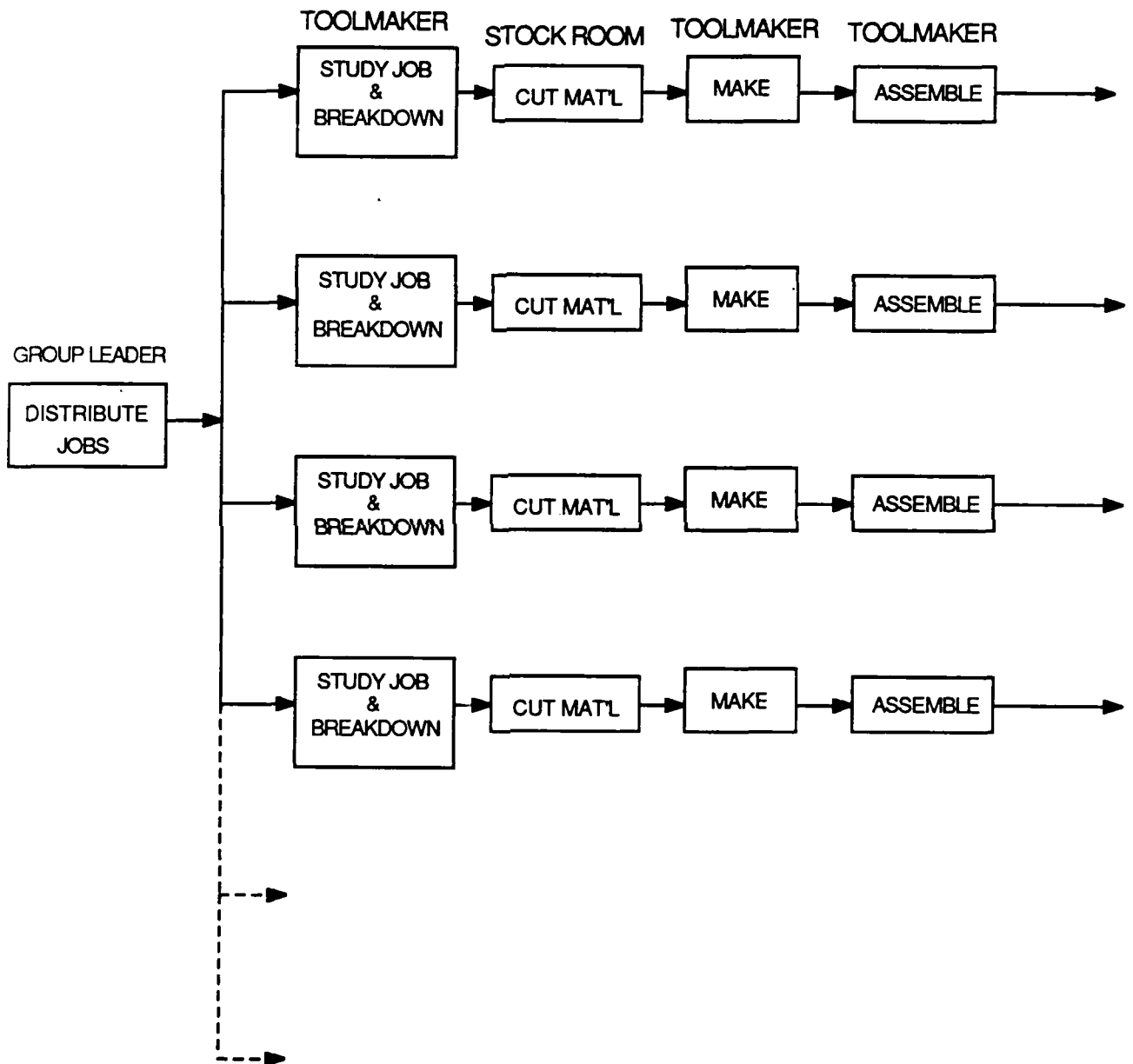


Figure 8.12 "As-Is" Model Shop Job Processing

# **JOB PROCESSING (MODEL SHOPS) TO BE**

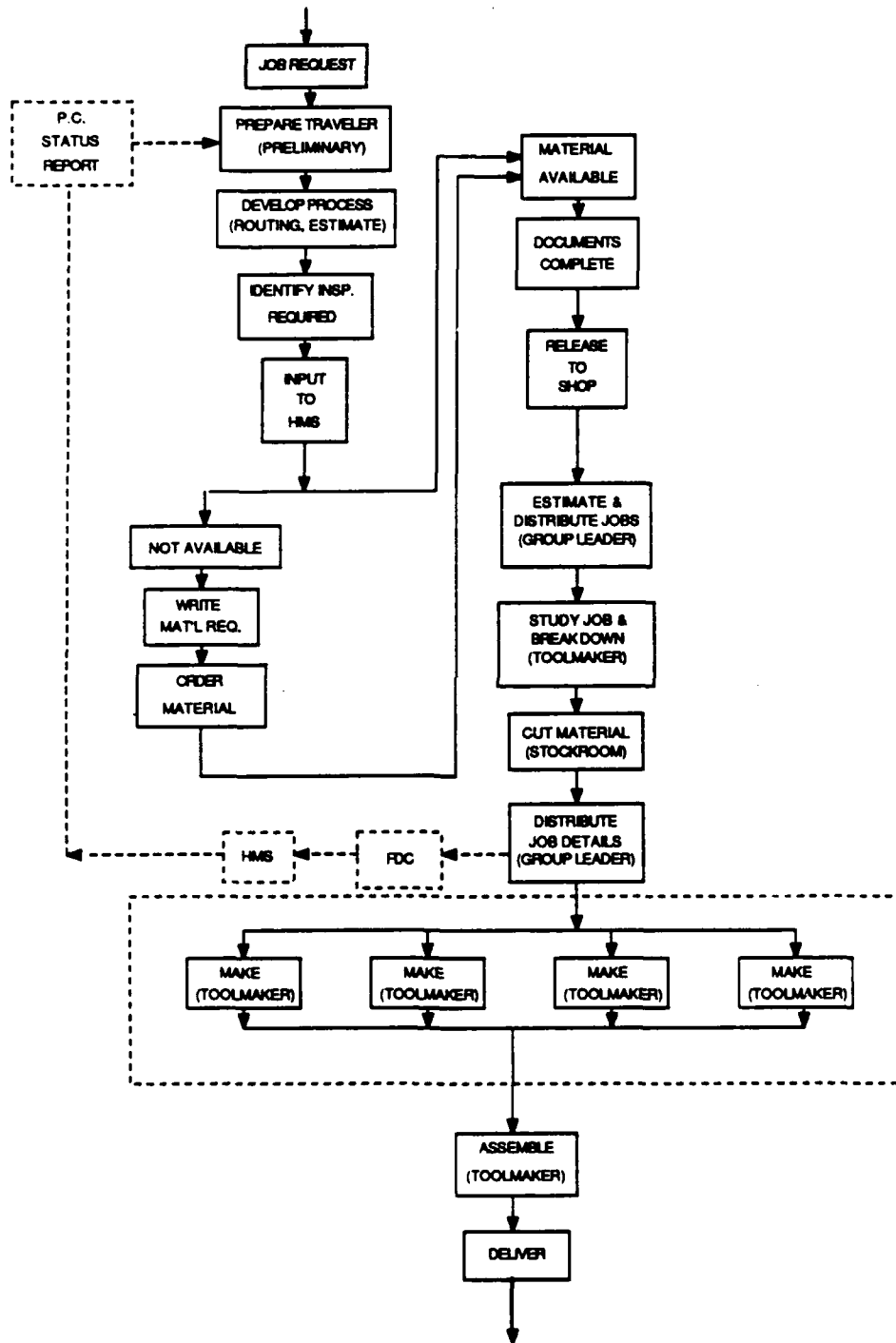


Figure 8.13 "To-Be" Model Shop Job Processing



## WORK CONTENT LOG SHEET

SLP ☐ S/R ☐

LOG ☐

PART NUMBER

JOB

PART DESCRIPTION

QTY.

ORG. EST

ADJ. EST

ACT.

DET. NO.

MACHINE TYPE	ACTUAL HOURS	EQUIP. TIED-UP
STUDY & PLANNING		
BENCH WORK		
BAND SAW		
LATHE		
MILL		
DRILL PRESS		
HEAT TREAT		
GRINDER MONOSET		
GRIND I.D.		
GRIND O.D.		
GRIND C'LESS		
SURFACE GRIND		
MISC.		
MISC.		

MACHINE TYPE	ACTUAL HOURS	EQUIP. TIED-UP
JIG BORE (MOORE)		
JIG BORE (DIXIE)		
PRESS WORK		
CNC KITAMURA		
MOOG MILL		
CNC TREE		
EDM		
ARBOR PRESS		
LAP		
HONE		
WELD		
INSPECT		
MISC.		
MISC.		

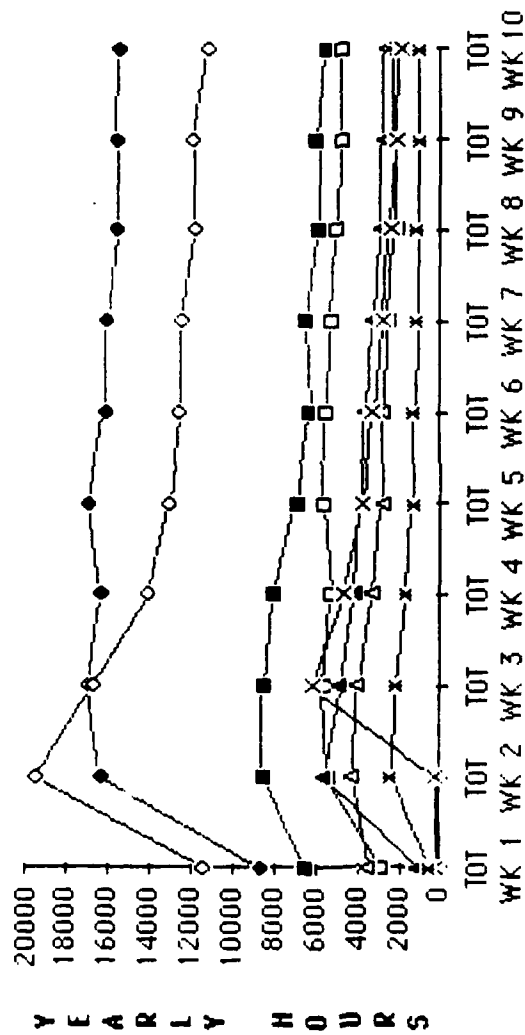
TOOL MAKER'S OPINION:  
WHAT DIFFERENT EQUIPMENT IS  
NEEDED TO IMPROVE THIS JOB?

NAME \_\_\_\_\_  
SSN \_\_\_\_\_

HOW MUCH TIME WOULD BE SAVED WITH THE NEW EQUIPMENT? \_\_\_\_\_ HOURS

Figure 8.14 Work Content Log Sheet

# SHOP LOAD CONSISTENCY



## STUDY SEGMENT

Figure 8.15 Model Shop Load Consistency

Results of the ten week data collection were summarized and shared with Fab senior management and staff. Direct meetings with both the SLP and S/R Tool Rooms departments were held to share the study results and announce the planning/study of the Tool Room consolidation was continuing.

Concerns were expressed by Toolmakers over the structure of a tool room with multiple operators running portions of the same tool or job simultaneously. In general, younger workers were more concerned about being "stuck" on a new CNC machine because older workers were intimidated by the possibility of learning to operate electronically controlled machine tools.

Fab senior management and staff met with counterparts of the business groups using Tool Room services at the SLP location. Based upon user projections of need/comfort in relying on a support service more than a hallway away, the proposed total move was tempered to a partial withdrawal. Approximately 40% of the employees were planned to be transferred to Stinson/Ridgway and 50% of the SLP Tool Room area planned to be vacated. To retain the desired level of service, within a reduced area, CNC machines were proposed for the SLP area. In order to justify/utilize the equipment, the new equipment was planned to be treated as a direct extension of the Stinson/Ridgway facility. The equipment would run two shifts. Off shift jobs would be of a selected, regularly recurring type for ease of scheduling. The technique of setting up one job on a corner of the table and the variable work on the opposite corner was planned to reduce changeover requirements.

Introduction of CNC technology to the Model Shops required absorption of more shop load to meet equipment utilization and internal return on investment requirements. The investigative parts list developed by the project core team, as discussed in Section 3 of the Project Overview, dealt with only 80% of the shop load expressed in hours. The remaining 20% was considered miscellaneous (low volume, high variety) and were not treated in the parts base. This low volume and high variety work load was used to assist in the economic justification and utilization of the proposed Model/Short Run Shop CNC equipment. These parts were added to the total yearly hours of the Model Shops. These additional hours were distributed to the Model Shop by equipment type, less the high volume part load removed for cells. They were then added to the annualized hours of the ten week Tool Room study to yield the total yearly "To-Be" Model Shop hours. This load represented conventional equipment hours. Sampling of the parts base indicated that CNC technology could be applied to absorb 60% of these turning, milling, grinding and miscellaneous machining operations. The mix of proposed CNC and traditional machining annual hours were used to determine Model/Short Run Shop equipment requirements.

New and transferred (surplused CNC vertical machining centers from the Pallet Cell) capital equipment was identified. This process is described in Section 11 of this segment of the final report. The Tool Room supervisors and Tech Mod team prepared a comparison list of equipment between the two facilities. All sheetmetal work, in support of Test Systems and Logistics Operations and Commercial Aviation Division support, together with equipment were identified to move to the Stinson/Ridgway facility. Machines, used to support these two areas, were consolidated. Further consolidations of excess current machines and equipment were prepared.

During weekly meetings with the other project segment teams a decision to combine the resources of the Model Shop/Short Run Shop with the Flexible Machining Area was made. This decision was based on the common equipment needs to support many of the same under utilized processes in both areas. By combining the two areas, utilization would increase, economic

justification would generally improve, and management confidence in the equipment purchase would be enhanced. The concept also lends itself to merging the types of work done in the different labor groups into reduced complex scheduling of work from start to completion. The resource capacities are also closer and better understood by the person doing the processing breakdown. The Flexible Machining Area benefits by having a larger capacity pool available for long term scheduled jobs.

Based upon the resources currently available, the equipment list was shortened and floor space gained. The Final Design (reference Section 4) documents the final floor space improvements, process flow paths with no loss in capability in the Tool Room area. Figure 8.16 shows the Stinson/Ridgway Model Shop/Short Run Shop layout. The down-sized St. Louis Park Tool Room layout is given in Figure 8.17.

MODEL SHOP/SHORT RUN SHOP  
STINSON/ RIDGWAY TO BE

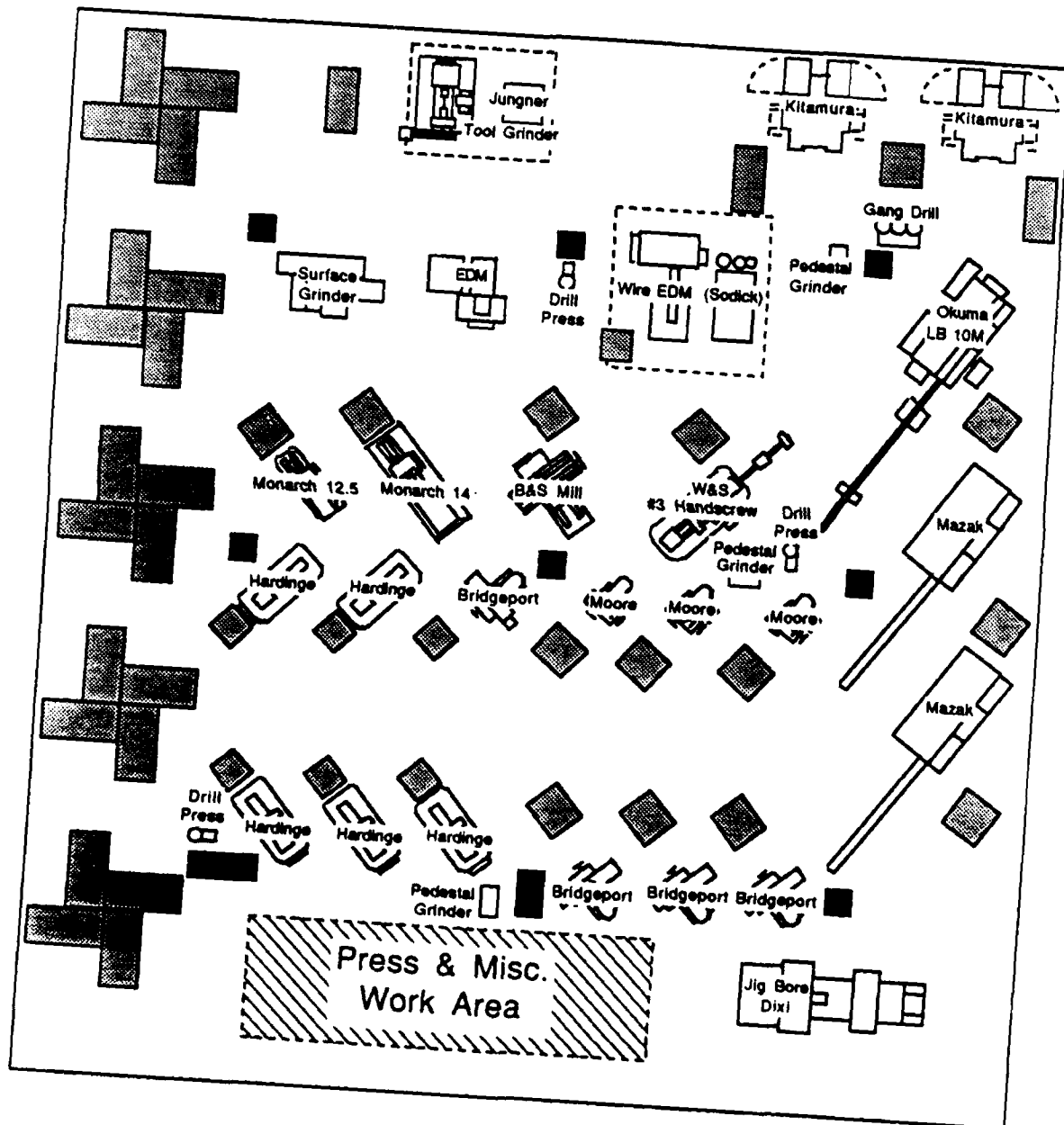


Figure 8.16 "To-Be" Stinson/Ridgway Model Shop/Short Run Shop

# ST. LOUIS PARK TOOL ROOM LAYOUT TO BE

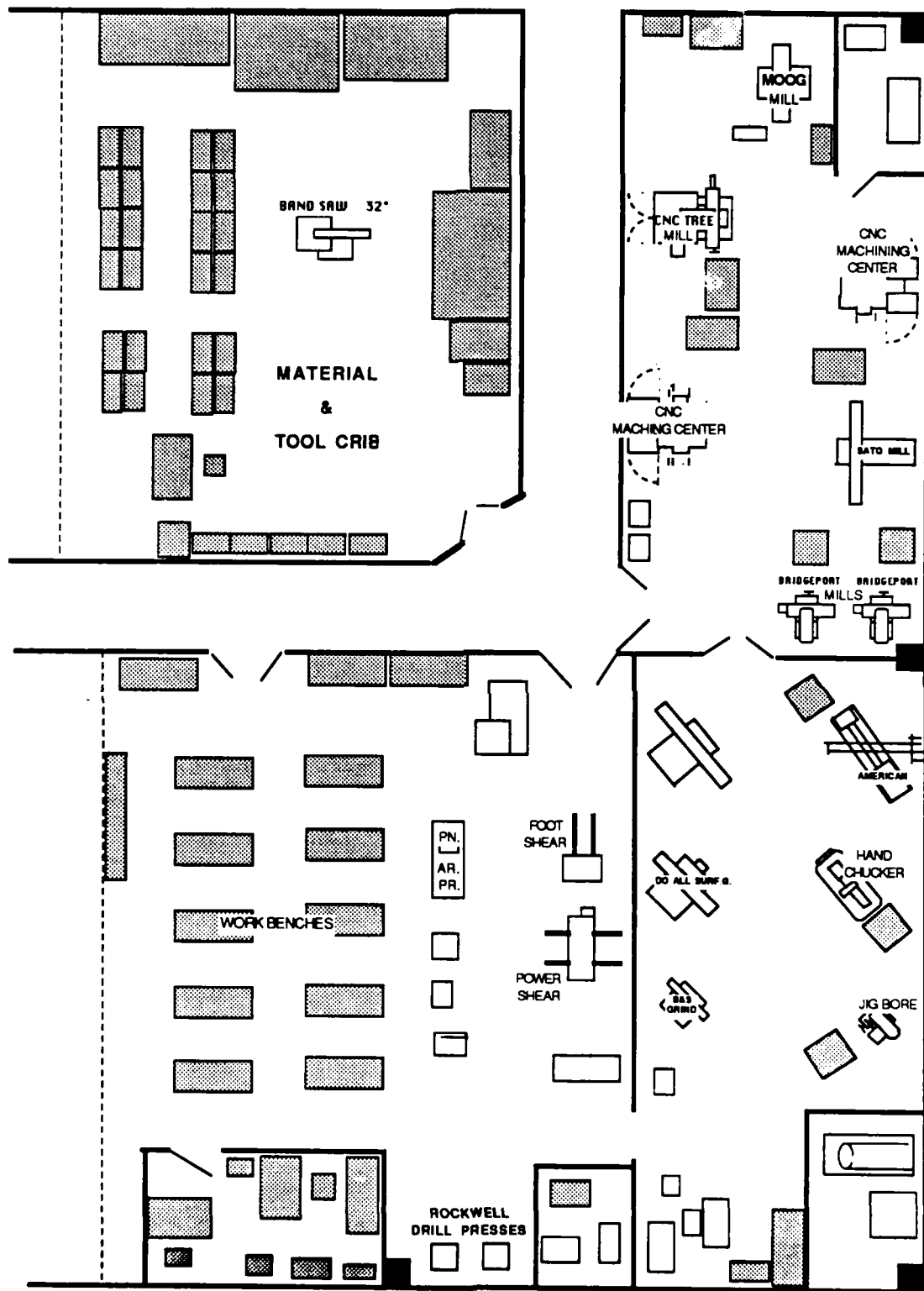


Figure 8.17 "To-Be" St. Louis Park Tool Room Layout

## SECTION 9

### SYSTEM/EQUIPMENT/MACHINING SPECIFICATIONS

The following are the specifications for the equipment which currently exists, and that which is to be acquired, for the Flex Shop, Short Run Shop and Model Shop.

The equipment marked with an asterisk (\*) has a specifications detail sheet at the back of this section.

Flex Shop: (to be acquired)

1. Okuma CNC Turning/Milling Center (2)\* (Figure 9.1)

- MODEL LB10-M
- 1 1/2" Diameter Bar Capacity
- Bar Feeder
- Chip Conveyor
- Fanuc Controls
- DNC Interface with RS-232 Port

2. Citizen CNC Turning/Milling Center\* (Figure 9.2)

- Model F12
- 1/2" Diameter Bar Capacity
- Bar Feeder Model CMBF 0412
- Chip Conveyor
- Fanuc Controls
- DNC Interface with RS-232 Port

3. Okuma CNC Turning/Milling Center\* (Figure 9.1)

- Model LB10
- Chucking capabilities with 2" diameter through hole
- Chip Conveyor
- Fanuc Controls
- DNC Interface with RS-232 Port

4. Tschudin 2 Axis CNC Grinder\* (Figure 9.3)

- Model Cylinderamatic Plus
- DNC Interface with RS-232 Port
- Automatic Wheel Dressing and Auto-Compensation
- Adjustable Tail Stock
- Linear and Circular Interpolation

5. Mitsubishi CNC Wire Cut EDM\*

(Figure 9.4)

- Model DWC70G
- Automatic Wire Threading
- Simultaneous 4 Axis Control
- DNC Interface with RS-232 Port
- Electronic Temperature Control
- Taper Cutting Ability

In addition to the above specified equipment, the following Honeywell-owned equipment will be utilized in the Flex Shop:

- CNC Lathe, 4 Axis (Hardinge)
- CNC Turning Center (Mori Sieki)
- ANC Lathe (Hardinge) (3)
- Auto Bar Lathe (Hardinge) (4)
- Hardinge Lathe (6)
- Machining Center A Axis (Kitamura)  
(CNC Rotary Axis)
- Machining Center T Axis (Kitamura)
- Machining Center (Kitamura)  
(no Rotary Axis)
- Nichols Mil
- Besly Double Disc Grinder
- International Bryant 1109
- Universal #1
- B & S PL CNC Grinder with Ceda Size #5
- Cincinnati Centerless Grinder
- Lapmaster Lapping Machine
- Serialization Equipment
- Convection Oven
- Pedestal Grinder (3)
- Excello Center Lap
- Gang Drill (4)

Short Run Shop: (to be acquired)

1. Mazak CNC Lathe (2)\*

(Figure 9.5)

- Model Quick Turn 8
- .187" Diameter Thru Hole
- Bar Feed System
- DNC Interface with RS-232 Port
- Fanuc Controls
- Power Chuck



2. Okuma CNC Turning/Milling Center\* (Figure 9.1)
  - MODEL LB10-M
  - 1 1/2" Diameter Bar Capacity
  - Bar Feeder
  - Chip Conveyor
  - Fanuc Controls
  - DNC Interface with RS-232 Port
3. Kitamura CNC Vertical Machining Center\* (Figure 9.6)
  - Model Mycenter 2
  - DNC Interface with RS-232 Port
  - 20 Tool Storage Capacity
  - Fanuc 11 MA with 14" CRT or equivalent prot dressing  
(instead of Faruc 6B control -- ref FIGURE 9.9)
  - 7.5 Horsepower rating
  - Axis Travel of 12" X 44" RS-232 Port
4. Jungner CNC Tool Grinder\* (Figure 9.7)
  - Model PSA-600
  - DNC Interface with RS-232 Port
  - Automated grinding wheel dressing
  - Contour Programming
  - Minimum 4 Axis capabilities
  - Automatic In-feed traverse in Y and Z
  - Minimum swing diameter of 10"
  - Table traverse of 9" X 11"
5. Mitsubishi CNC Wire Cut EDM\* (Figure 9.4)
  - Model DWC70G
  - Automatic Wire Threading
  - Simultaneous 4 Axis Control
  - DNC Interface with RS-232 Port
  - Electronic Temperature Control
  - Auto Wire Squaring
6. B & S 3 Axis CNC Surface Grinder\* (Figure 9.8)
  - Model Techmaster CNC Surface CNC818
  - Part Gauging
  - DNC Interface with RS-232 Port
  - Automatic Dressing
  - Self-diagnostic on all circuits
  - Dynamic Fixture Offset

Model Shop/Short Run Shop - Stinson/Ridgway: (Honeywell-owned equipment)

- Bridgeport Vertical Mill (4)
- B & S Universal #2 Mill
- Hardinge Lathe (5)
- Monarch Lathe 12.5"
- Monarch Lathe 14.5"
- W & S #3 Universal Turret Lathe
- Moore #1 Jig Borer (3)
- Dixie Jig Borer
- EDM (Electrode)
- Kitamura with GMB-2 CNC
- DO ALL Bandsaw (2)
- Engleberg Belt Sander 8"
- Grob Speed File
- Disc Sander
- Die Holder Punch
- Roll Form
- Tube Bender
- Press Brake
- Notcher
- Shear
- Punch Press
- Hydraulic Arbor Press (Large)
- Handscrew Arbor Press (Large)
- Handscrew Arbor Press (Small)
- Hand Lever Arbor Press (Small)
- Pedestal Grinder
- Rockwell Drill Press
- B & S Surface Grinder

Model Shop (St. Louis Park): (to be acquired)

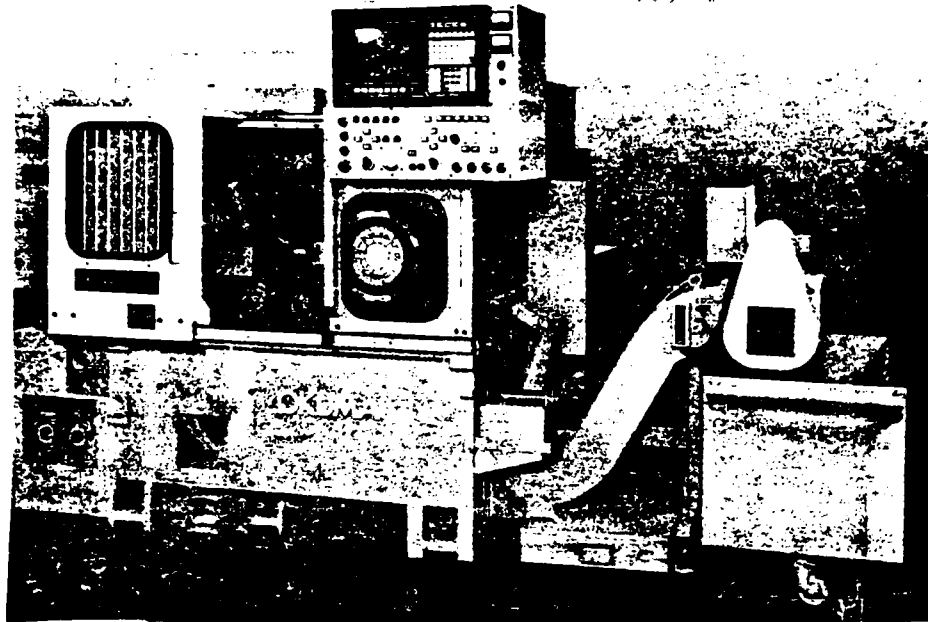
1. Kitamura CNC Vertical Machining Center (2)\* (Figure 9.6)

- Model Mycenter 2
- DNC Interface with RS232 Port
- 20 Tool Storage Capacity
- Fanuc 11 MA with 14" CRT or equivalent prot dressing  
(instead of Faruc 6B control)
- 7.5 Horsepower rating
- Axis Travel of 12" X 44" RS-232 Port
- Machine dimensions 106" X 73"

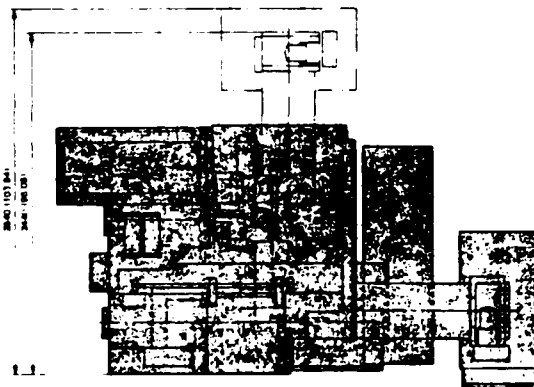
Model Shop - St. Louis Park: (Honeywell-owned equipment)

- CNC Tree
- Bridgeport Mill (2)
- Moore #1 Jig Borer
- Hardinge Lathe
- Manarch Lathe (Medium)
- Rockwell Drill Press
- DO ALL Surface Grinder
- B & S Grinder #1A
- DO ALL Cut-off Saw
- DO ALL Bandsaw
- Arbor Press
- Notcher
- Bench with Arbor Press
- Punch
- Shear 12" (Small)
- Foot Shear
- Power Shear
- Belt Sander - Rockwell
- Miller Welder
- Pedestal Grinder (3)
- Moog Mill

# OKUMA CNC TURNING/MILLING CENTER MODEL: LB10-M



## Machine Specifications



LB10-M	
<b>CAPACITY</b>	
Number of controlled axes	3
Max turning diameter	ø150 mm (ø5.91")
Max work length (chuck work)	120 mm (4.72")
<b>HEADSTOCK &amp; MAIN SPINDLE</b>	
Spindle diameter at front bearing	ø80 mm (ø3.15")
Spindle nose	ø140 mm (ø5.51") flat
Internal taper	ø60 mm (ø2.36") 6° taper
Bore diameter	ø53 mm (ø2.09")
Number of gear ranges	2 auto, infinitely variable
Range of spindle speed	60 - 6000 rpm
<b>CROSS SLIDE &amp; CARRIAGE</b>	
Carriage travel (Z axis)	285 mm (11.22")
Cross slide travel (X axis)	150 mm (5.91")
Rapid traverse rate, both axes	12 m/min (472 ipm)
Cutting feedrate, both axes	0.001-1000.00 mm/rev (0.0001-40 ipr)
<b>C AXIS</b>	
Controlled angle	360° (0.001° increments)
Rapid feedrate	30 rpm
<b>TURRET</b>	
Type & no. of tool stations	V12 (turning/rotary tools)
Tools OD/ID	ø20/ø32 mm (ø0.79/ø1.26")
<b>ROTARY TAIL</b>	
Spindle speeds	180 - 3000 rpm
Number of gear ranges	1
<b>MOTORS</b>	
Main spindle drive	VAC 7.5/5.5 kW (10/7.5 hp)
Rotary tool	Brushless 3.6 kW (4.8 hp)
C axis	Brushless 0.5 kW (0.7 hp)
<b>FLOOR SPACE REQUIREMENTS</b>	
NET WEIGHT OF MACHINE	1780 x 2430 mm (170.08 x 95.67") 3600 kg (7920 lb)

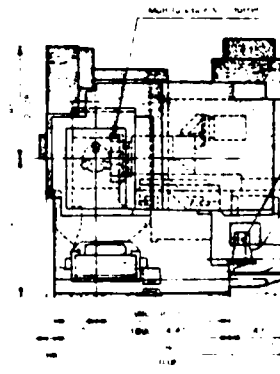
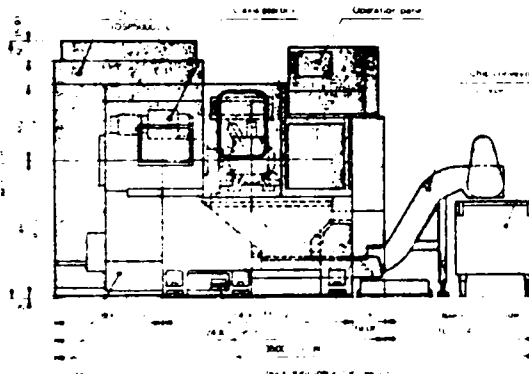
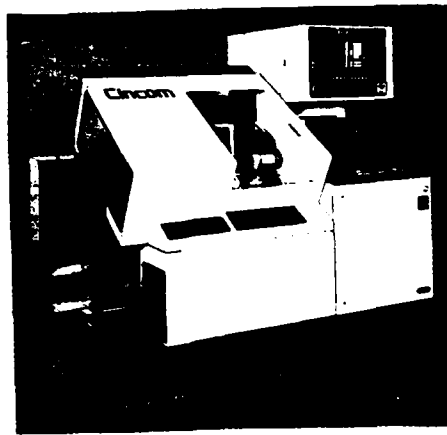


Figure 9.1 Okuma CNC Turning/Milling Center

# CITIZEN CNC TURNING/MILLING CENTER MODEL: F-12



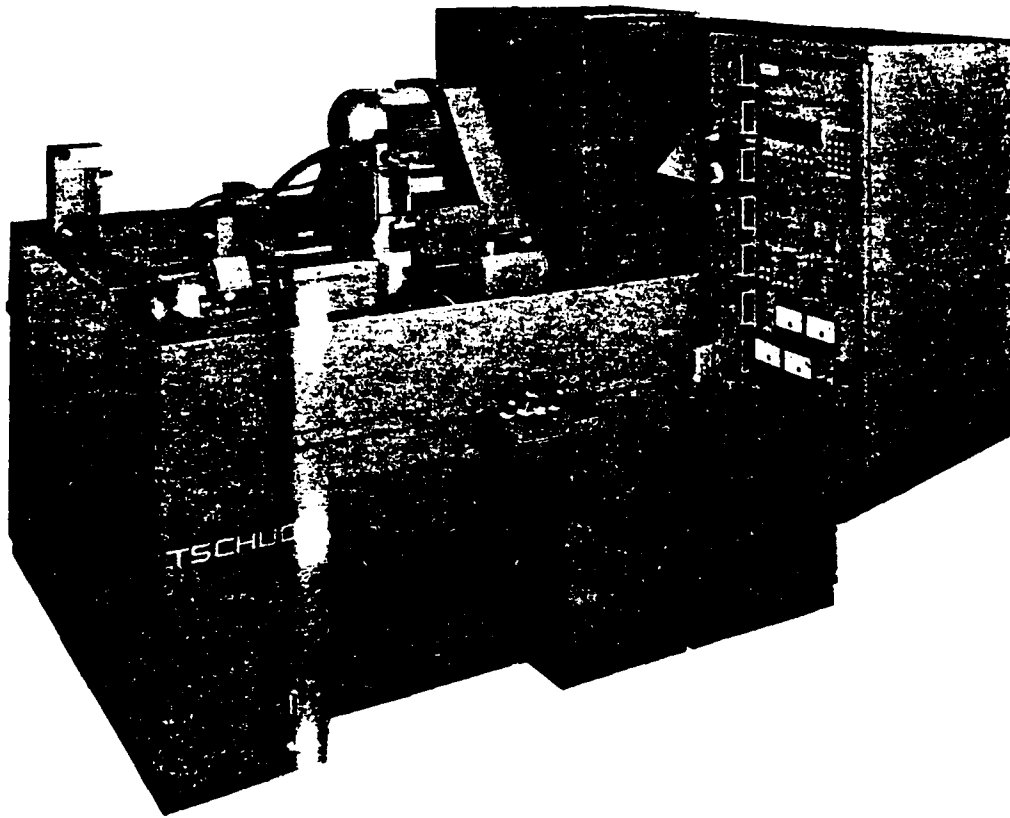
## F-Series Machine Specification

	F12	F16	F20	F25
Maximum Working Diameter	0.5"	0.63"	0.78"	1.0"
Minimum Working Diameter		0.032"		0.118"
Maximum Length Per Chucking	4.92"			7.87"
Number of Tool Stations		10		
Main Spindle Speeds (rpm)	220/10000	180/8000	180/7500	180/7000
Spindle Speeds Rotary Tools		Low Speed Turret: 200 to 1000 rpm High Speed Turret: 300 to 6400 rpm		
Maximum Drilling Diameter	0.315"			0.5"
Maximum Tap or Die Diameter	1/4" 20			5/16" 20
Standard Tool Shank	1/2"			3/4"
Maximum Feed Rate		200" per minute		
Rapid Traverse X & Z Axes (IPM)		390" per minute		
Minimum Indexing Increment of Main Spindle		1° pulse		
Minimum Input Increment		0.00004"		
Input Coding	EIA/ISO	EIA/ISO	EIA/ISO	EIA/ISO
Main Spindle Motor (30 min. rating)		7.3 HP		
Main Spindle Motor Continuous		5 HP		
Total Electric Power Spec'd		13 KVA		
Weight	5100 lbs			6000 lbs
Guide Bushing Holder		Synchronous Rotary		
Guide Bushing Type (Southwick & Mrister)	SD125R	0201	TS0200	CD25
Collet Type	TF16		TF25	TF30
Drilling Sleeve Collet		TF8 or FR16		
Rotary Tool Collet	0136 or ER11			TF8 or ER16
Pick Off Collet	TF16			TF25
Maximum Bar Length		12"		
Citizen Quick Bar	CMBF 0412	CMBF 0616	CMBF 0620	CMBF 0625

Figure 9.2 Citizen CNC Turning/Milling Center

# TSCHUDIN 2-AXIS CNC GRINDER MODEL: CYLINDRAMATIC PLUS

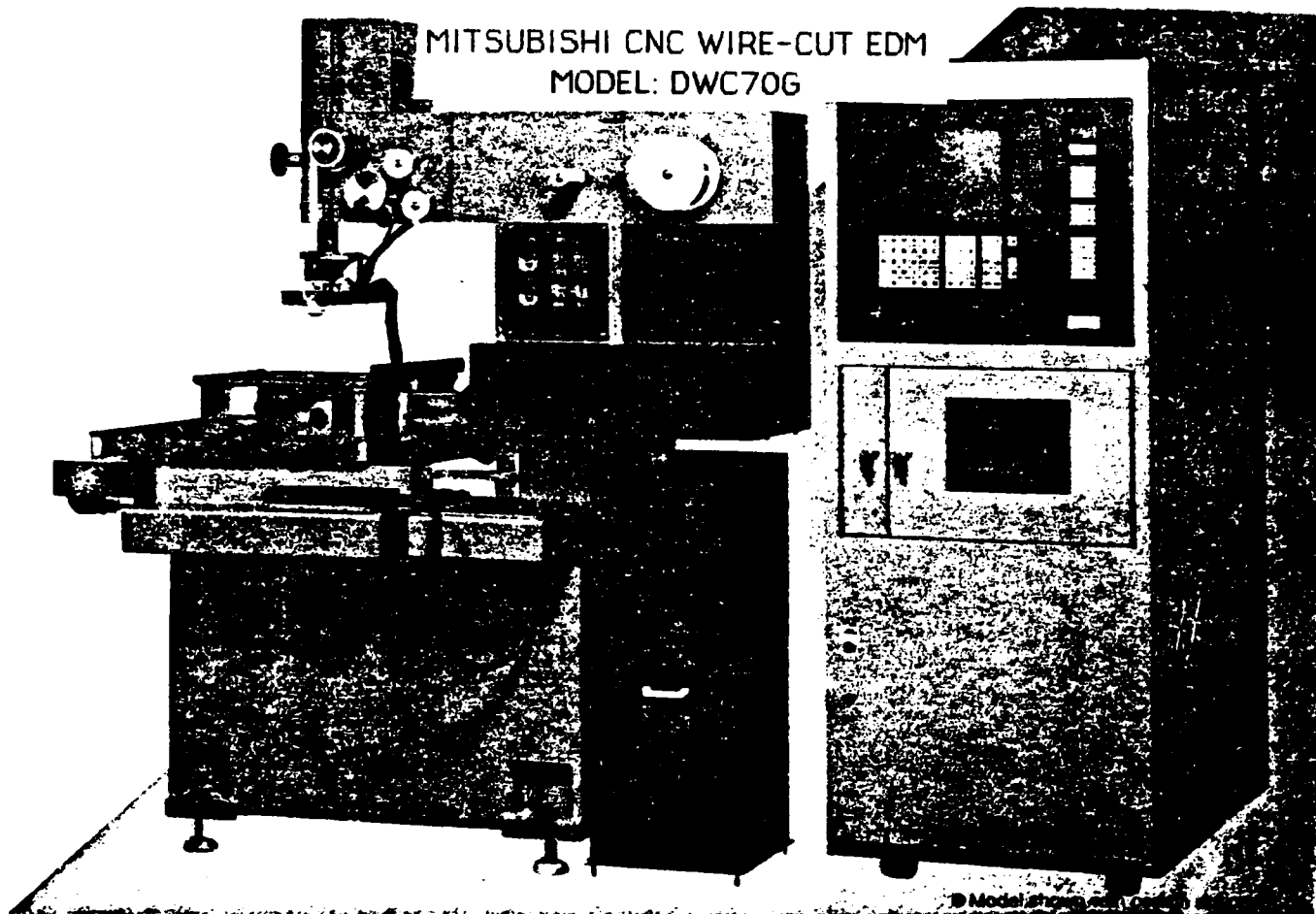
STRAIGHT AND  
ANGLE-HEAD



<b>Table</b>	
Distance between centers	12", 20", 28"
Swing	8"
Traverse movement	0", 4", 16", 24"
Maximum traverse speed for positioning	196"/min
Traverse speed for grinding	19" to 196"/min
Swiveling range	±8°
<b>Wheelhead</b>	
Wheel diameter	14", 20"
Wheel width, max	2", 4", 5"
Wheel bore	5" - 8"
Motor	4 HP - 5 HP
Swiveling range	±3° - 5°
Infeed	4"
Minimum infeed increment	0.00020"
<b>Workhead</b>	
Spindle taper	Morse Taper 4
Spindle nose thread	M 48 x 5
Swiveling range	460°
Spindle speed, infinitely variable	10-500 RPM
Motor	7.5 HP

<b>Tailstock</b>	
Taper of center bore	Morse Taper 4
Travel of center	8"
<b>Hydraulic Unit</b>	
Capacity of tank	15 gal
Motor	1.5 HP
<b>Coolant Unit</b>	
Capacity	55 gal
Flow rate	64 GPM
Motor	1.25 HP
<b>Drives</b>	
Servo motors	2.4 HP each
<b>Machine</b>	
Overall dimensions	72" H x 110" W x 86" L 72" H x 110" W x 100" L 72" H x 110" W x 108" L
Power consumption	15 kVA
Approx. weight	8,000 lbs

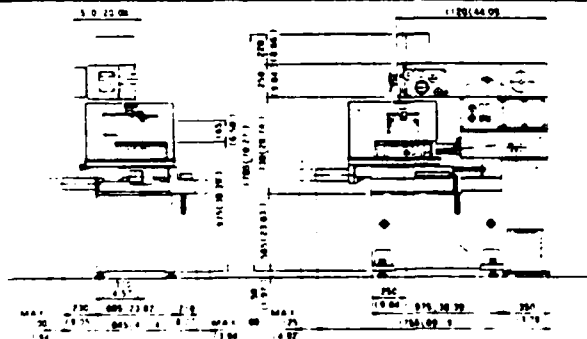
Figure 9.3 Tschudin 2 Axis CNC Grinder



Machine-Unit Specifications			
Max. workpiece dimensions	[mm]	350 × 350 × 160	
(ref. W × D × H)	(in)	13.78 × 13.78 × 6.299	
Max. workpiece weight	[kg] (lb)	150	330
Table dimensions	[mm] (in)	420 × 385	16.535 × 15.157
Machining range (X-Y)	(mm) (in)	250 × 200	9.843 × 7.874
Table fast-feed speed	[mm/min] (in/min)	800	31.496
Wire diameter	(mm) (in)	0.05 ~ 0.3	0.00196 ~ 0.0118
Max. wire-feed rate	[mm/sec] (in/sec)	180	7.086
Wire tension	[g] (lb)	200 ~ 2500	0.44 ~ 5.5
Overall dimensions	[mm]	1755 × 1045 × 1785	
(W × D × H)	(in)	69.19 × 41.14 × 70.27	
Machine-unit weight	[kg] (lb)	900	1980

\* For reference only

#### Outlines and dimensions in mm (in)



#### Layout in mm (in)

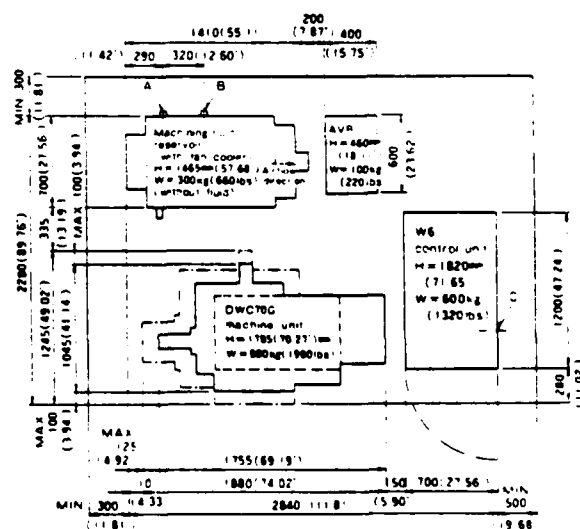
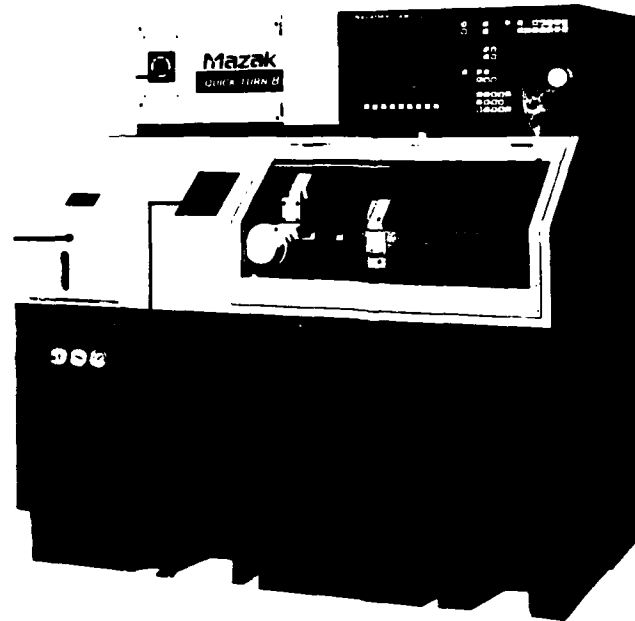


Figure 9.4 Mitsubishi CNC Wire Cut EDM

## MAZAK CNC LATHE MODEL: QUICK TURN 8



### MACHINE SPECIFICATIONS

ITEM	CHUCKER	UNIVERSAL
Max. swing	11 dia	10"
Std. cutting dia./Max. cutting dia.	4"/8"	
Cutting length	JIS A2.5/1.97"	
Spindle nose/spindle bore dia.	45 ~ 4500 rpm	
Spindle speed	Octagonal drum turret/8	
Turret type/No. of tools	7" dia /2200 Lbs	
Hi-index coupling dia./clamping force	X-axis 3.75", Z-axis 11.4"	
Stroke of turret (X axis/Z axis)	X axis max. 470 IPM, Z-axis max. 945 IPM	
Rapid traverse		19"/MT No. 3
Tailstock quill dia./center		2.95"/14.25"
Stroke of tailstock quill/body		Manual switch
Tailstock quill control		
Main motor (Cont./30 min. rating)	AC7.5HP (5.5 kW)/AC10HP (7.5 kW)	
Overall electrical capacity	19.2 KVA	
Machine weight	5850 Lbs	6000 Lbs

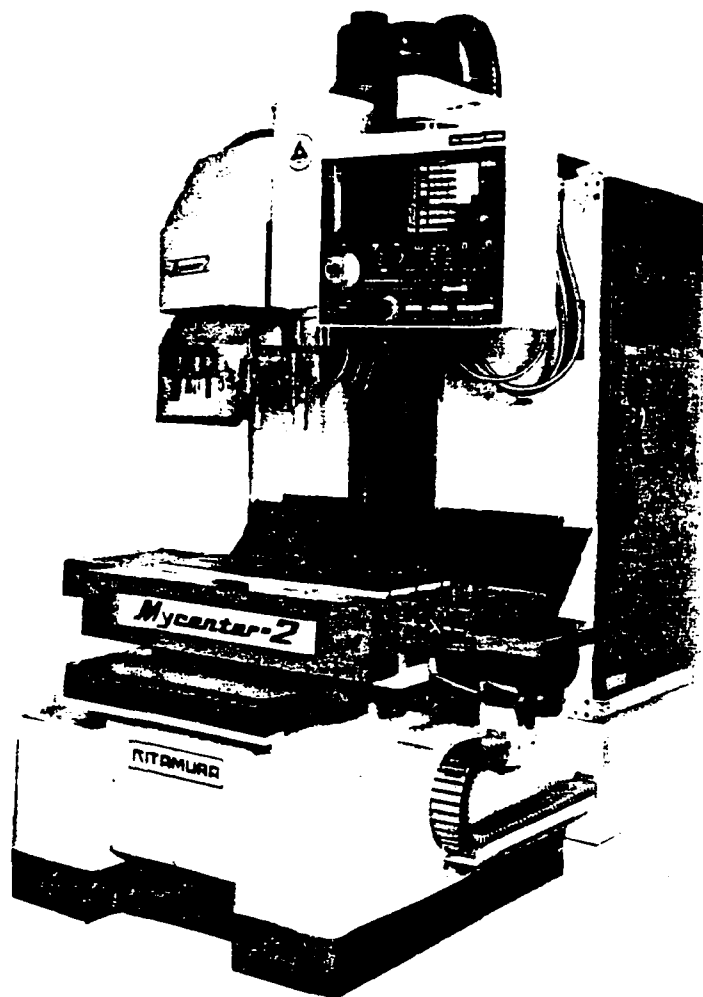
\* indicates option

### FANUC CNC SPECIFICATIONS

No. of controlled axis	2 axis (X, Z) simultaneous 2-axis
Control system	Positioning: linear and circular interpolation
Command system	Absolute/Incremental
Least input increment	X, Z axis 0.0001 inches (X axis dia.)
Max. programmable dimension	X, Z axis ±999.9999 inches
Cutting feed rate	X, Z axis 0.000001 ~ 9.999999 ipr
Memory capacity	CMOS memory: 65 feet
Tool offset A	16 pairs in memory: ±99.9999 inches
MDI & CRT	Hard type MDI and 9" monochrome CRT character display
Background programming	Simultaneous machining and programming

Figure 9.5 Mazak CNC Lathe





CNC MYCENTER - 2  
KITAMURA SUPER PRECISION  
HIGH SPEED VERTICAL MACHINING CENTER

SPINDLE:

Type - BT. 35  
Speed - 160 to 7000 RPM  
Motor - 7.5 HP  
Spindle Oil Cooled

TABLE SIZE - 13" - 30"

TRAVEL:

Longitudinal (X-Axis)	20"
Cross (Y-Axis)	13"
Vertical (Z-Axis)	18"

FEED RATES:

Rapid Feed (X,Y Axis)	472"/Min.
(Z Axis)	354"/Min.

BT - 35 Tooling System

TOOL CHANGER:

Tape controlled-random selection  
Max. No. of tools in magazine 16  
Max. Tool Size (Dia. x Length) 3"x10"  
Max. Tool Weight 8.8 lbs.

TOOL CHANGING TIME:

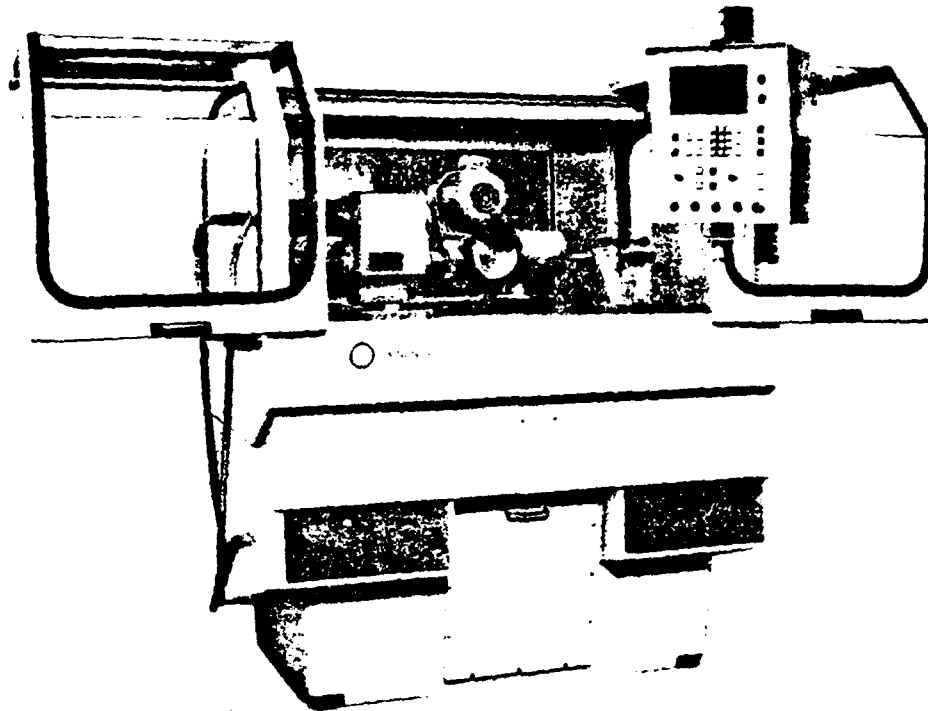
Tool to Tool	4 Seconds
Chip to Chip (With tool Orient.)	10 Sec.

CONTROL HIGHLIGHTS - "6MB FANUC SYSTEM"

- |                                       |                                  |
|---------------------------------------|----------------------------------|
| o 3 Standard (X,Y,Z) controlled axis. | o Cutter Length compensation.    |
| o CRT character display.              | o Tool length measurement.       |
| o Constant tangential feed rate.      | o Self diagnostic function.      |
| o Tool position offset.               | o Programming of Absolute zero.  |
| o Tape punch interface.               | o Multiple part program storage. |
| o Inch/Metric conversion.             | o Cutter compensation.           |
| o Cutter radius compensation C        | o Tool length compensation.      |
| o Helical cutting.                    | o Mirror image.                  |

Figure 9.6 Kitamura CNC Vertical Machining Center

# JUNGNER CNC TOOL GRINDER MODEL: PSA-600

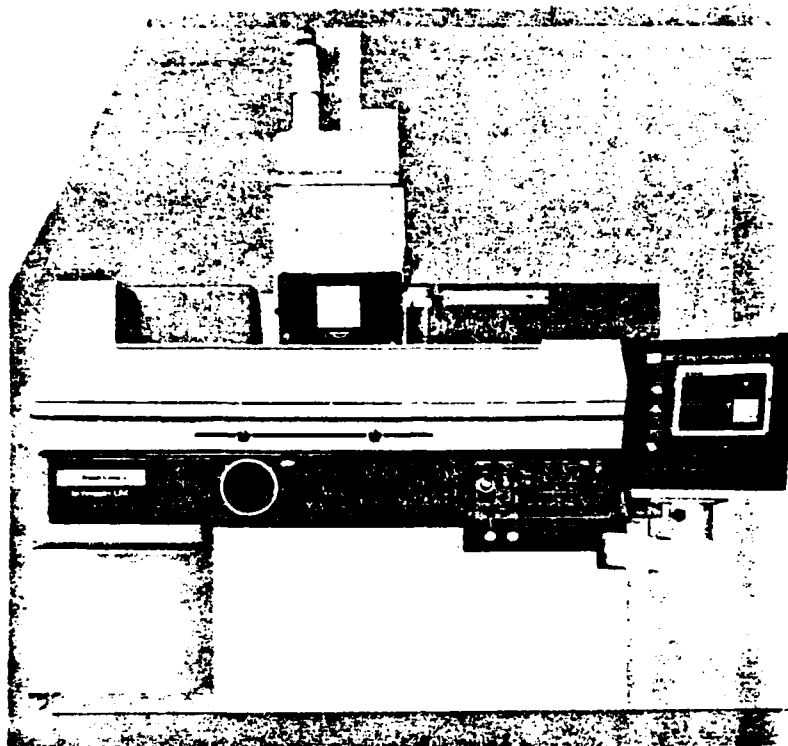


## Technical data

Worktable surface	52"×6" (1300×150 mm)	Grinding spindle tiltable	±90°	±90°
Longitudinal travel	24" (600 mm)	Grinding wheel diameter, max	8" (200 mm)	
Cross travel	12" (300 mm)	Grinding wheel diameter, standard	6" (150 mm)	
Vertical travel	12" (300 mm)	Output of grinding motor	3 hp (2.2 kW)	
Measurement resolution for longitudinal, cross and vertical travel	0.000040" (0.001 mm)	Grinding wheel speeds	1500/2000/4500/6000 r.p.m.	1500/2000/4500/6000 r.p.m.
Maximum centre distance	35" (900 mm)	Electrical connection	220 or 440 V, 3 ph 60 cycle	220 or 440 V, 3 ph 60 cycle
Centre height above work table	6.25" (160 mm)	Other voltages available at extra charge		
Max. swing between centres	12" (300 mm)	Length	60" (1500 mm)	
Horizontal rotation of workhead	360°	Depth	44" (1100 mm)	
Taper for workhead	ISO 50	Height to centre workhead	50" (1260 mm)	
Runout accuracy for workhead	0.000080" (0.002 mm)	Weight	4850 lb (2200 kg)	
Smallest programmable division	0.001°	Electrical cabinet, width	30" (750 mm)	
	(0.000040" (≈0.001 mm p.d. 120 mm diam))	depth	30" (750 mm)	
Screen, number of rows	12	height	63" (1600 mm)	
number of characters per row	40	weight	880 lb (400 kg)	
texts currently available in	English, German	Floor area required, machine + cabinet	7.4×9.4 ft (2.25×2.85 m)	
Grinding spindle diameter	3" (80 mm)	Shipment volume, three cases	26.5 ft³ (7.5 m³ together)	
Grinding spindle rotatable	360°	Shipment weight	6600 lb (3000 kg together)	

Figure 9.7 Jungner CNC Tool Grinder

**BROWN & SHARP 3-AXIS CNC SURFACE GRINDER  
MODEL: TECHMASTER CNC-818**



**TECHMASTER CNC**

**All Models**

Table Capacity	6"x18" (150mmx460mm)	8"x18" (200mmx460mm)	8"x24" (200mmx610mm)
Spindle Drive	2HP Direct (Std) 7" Wheel 2HP Oriflex (Opt) 8" Wheel 3HP Direct (Opt) 12" Wheel	2HP Direct (Std) 7" Wheel 2HP Oriflex (Opt) 8" Wheel 3HP Direct (Opt) 12" Wheel	3HP Direct (Std) 12" Wheel 5HP Direct (Opt) 14" Wheel

CNC Controller: General Numeric Primo SG 3-axis with point-to-point positioning

**Model #1** Downfeed (Y-axis) and Crossfeed (Z-axis) NC Controlled with Hydraulic Table traverse

**Model #2** Downfeed (Y-axis) and Table (X-axis) NC Controlled with Hydraulic Crossfeed

**Model #3** Table (X-axis) and Crossfeed (Z-axis) NC Controlled with Manual Downfeed.

**Model #4** Table (X-axis), Downfeed (Y-axis) and Crossfeed (Z-axis) NC Controlled

**With These Certified Precision Capabilities**

Surface Waviness (Proficorder)	Within .000025" (0.0006mm)
Test Bar across Table	Straight within .0001" (0.0025mm)
Test Bar along Table (18" 450mm long) 618 & 818 Models	Straight within .0001" (0.0025mm)
Slot Grind (15" 380mm long) 618 & 818 Models	Sides Parallel within .0001" (0.0025mm)
Test Bar along Table (22" 560mm) 824 Model	Straight within .00015" (0.0038mm)
Slot Grind (22" 560mm long) 824 Model	Sides Parallel within .00015" (0.0038mm)
Finish	5 Microinches (0.1 $\mu$ m) AA or better

**Figure 9.8 Brown & Sharp 3 Axis CNC Surface Grinder**

## SECTION 10

### TOOLING SPECIFICATIONS

No special consideration for tooling is required to implement this project segment. Perishable and multi-purpose tooling are used for the majority of existing processes. Special cutting tools and holding fixtures are already available for existing parts that will be assigned to the new areas. Modification to existing holding fixtures, to mount to proposed new equipment, and special cutting tools etc. will be charged, per existing requirements, to the specific customer/charge tally for the part.

Adapters for standard cutting tools to fit specific proposed machines are part of the capital requirements. Standard modular or adaptive fixtures, of a general purpose nature, available with machine tools and will be part of the equipment expenditure.

Reprocessing by Production Engineering, required to document new processes, adapt existing part processes, or combine operations sequences will be completed by the existing Engineering Action Request system in Fab. All new or revised tool, gauges, fixtures or operator instructions will be reviewed and approved by Production Engineering, Quality Engineering, Industrial Engineering and Production Control.

## SECTION 11

### VENDOR/INDUSTRY ANALYSIS/FINDINGS

An industry study was conducted to identify the companies which are capable of supplying and meeting the requirements of the following machinery:

#### FLEX SHOP

- CNC-Turning Machine/Live Tooling and a 1 1/2 to 2 inch diameter bar capacity.
- CNC-Turning Machine/Live Tooling and a 1/2 inch diameter bar capacity.
- CNC-Cylindrical Grinder.
- CNC-Wire-Cut EDM.

#### MODEL SHOP/SHORT RUN SHOP

- CNC-Turning Machine/Live Tooling and a 1 3/4 to 2 inch diameter bar capacity.
- CNC-Small Precision Chucker.
- CNC-Tool and Cutter Grinder.
- CNC-Wire-Cut EDM.

#### SELECTION CRITERIA

An industry search was conducted to identify the companies that would be capable equipment suppliers/integrators. In view of the many ongoing advances in machine tool automation and metal removal technology, we tend to think of modern mechanical manufacturing (CNC-Computer Numerical Control) as a highly productive and efficient process. The information for preparing this evaluation was obtained by:

- Conducting an extensive literature search (local and foreign), Thomas Register, technical journals, advertisements, etc.
- Contacting suppliers.
- Visiting a few companies.

In order to obtain detailed information, part drawings, and in some cases sample parts, were prepared and sent to selected companies to obtain first hand information and delivery lead time estimates.

After review and assessment of the companies active in the market, several vendors were selected based on the following criteria (not listed by priority or importance):

- Capability to deliver.
- Servicing and training support.
- Machine requirements and capabilities.
- Project support in supplying pertinent data.
- Size and financial stability (as indicated by Dunn and Bradstreet reports).

#### EVALUATION CRITERIA

The vendors were supplied with part prints and generic equipment requirements. They were required to give delivery time estimates, detailed equipment specifications and current price quotes. Following the receipt of the quotes and data, an equipment file (Figure 11.1) was prepared for each piece of equipment. The data was reviewed and a final evaluation made based on pricing and machine specifications. The results of this analysis are described below. Although tool cost, which reflects both the price of the equipment and its durability, is important, it is not necessarily the paramount criterion. What is paramount, depending on objectives, is either minimum total cost of the machining operation or maximum production rate. Equipment utilization is very high because everything necessary to produce the parts is in one location while one operator runs multiple machines in the cell for optimum productivity.

The following is a list of companies contacted during the survey:

AMT-Anderson Machine Tool Company, Inc. - St. Paul, MN.

Concept Machine Tool Sales - Minneapolis, MN.

Hales Machine Tools Inc. - Minneapolis, MN.

Productivity Inc. - Minneapolis, MN.

Q & S Machine Tool Company - Minneapolis, MN

Ellison Machinery Company - Minneapolis, MN.

Fay Machinery Company - Minneapolis, MN.

Hegman Machine Tool Inc. - Minneapolis, MN.

High-Tech Systems Inc. - Plymouth, MN.

Northwest Machine - Minneapolis, MN.

Duncan Company - Minneapolis, MN.

Stone Machinery - Minneapolis, MN.

## VENDOR - EQUIPMENT AVAILABILITY CHART

VENDOR	TYPE OF CNC EQUIPMENT					
	TURNING	VERTICAL MACH. CNTR	EDM WIRE CUT	O.D. GRINDER	C'LESS GRINDER	JIG GRINDER
ANDERSON MACHINING	X	X		X	X	
CONCEPT MACHINING	X	X	X	X		X
CINCINNATI MILACRON		X		X		
ELLISON MACHINING	X	X				X
FAY MACHINING	X	X	X			
MILTON GRANRULST	X	X				
HEGMAN MACHINING	X	X		X		
HIGH-TECH		X	X			
HALES MACHINE CO.	X	X	X			
KEARNEY & TRECKER		X				
MIDWAY MACHINING						
PRODUCTIVITY	X	X	X	X	X	
Q & S	X	X	X	X		
RAM-CENTER						
W & S	X					
ASEA						
AGIETRON			X			
DANOBAT	X			X	X	
HIRSCHMANN	X				X	
INDEX	X					
JAPAX			X			
OKUMA	X					
STUDER				X		
TSCHUDIN				X		
TOYODA				X		
YAMAZEN	X					
CITIZEN	X					
NORTHWEST MACH.	X	X	X	X		
DUNCAN COMPANY				X		
STONE MACHINERY	X	X		X		

Figure 11.1 Model/Short Run/Flex Shop Vendor Equipment Availability Chart

## SELECTION CRITERIA

The selection criteria for potential equipment suppliers consisted of several levels of response and evaluation. They were also directed to be completely responsive to the specification, itemizing exceptions or alternatives proposed. Price for the equipment certainly would be a key evaluation point, but not the only one. It was asked that these vendors give time delivery estimates, base equipment cost and cost of required accessories to aid in the evaluation.

As a result, the following equipment and vendors were chosen:

### FLEX SHOP

- Ellison Machine
  1. Okuma CNC-Turning Machine Model LB10-M (2 inch diameter bar capacity).
  2. Citizen CNC-Turning Machine Model F12 (1/2 inch diameter bar capacity).

These two machines were selected based on systems/equipment/machine specification in Section 9. The equipment incorporates some of the most advanced engineering features and innovations available today. These features, combined with optionally available automated peripherals such as live tooling, automatic gauging, robot loading as a option, and tool life management, etc. will provide a complete production system from raw material to completed product with a minimum of operator attendance. Accuracy is of great importance.

- Productivity Inc. - Tschudin Model CNC-Cylindramatic Cylindramatic

This machine was selected for its state-of-the-art technology in design, construction, precision and computerized numerical controls. This equipment demonstrated greater versatility and ease of operation. The machine is a fully automatic production machine, features the ability to grind multiple diameters and shoulders with maximum precision at high production rates.

- High-Tech Systems Inc. - Mitsubishi Wire-Cut EDM Model DWC-70G.

This was selected because of its embodying sophisticated high-precision machining expertise. The newly developed control unit and a host of new functions result in a quantum leap in user friendliness and reliability, achieving an astonishing level of machining precision.

### MODEL SHOP/SHORT RUN SHOP

- Ellison Machine Okuma
  - CNC-Turning Machine Model LB10-M(2 inch diameter bar capacity).

This machine was selected based on systems/equipment/machine specification in Section 9. The equipment incorporates some of the most advanced engineering features and innovations available today. These features, combined with optionally available automated peripherals such as live tooling, automatic gauging, robot loading as a option and tool life management, etc. will provide a complete production system from raw material to completed product with a minimum



of operator attendance. Accuracy is of great importance.

- Northwest Machine - Mazak CNC-Lathe Model Quick Turn 8.

This machine was selected because the equipment incorporates some of the most advanced engineering features and innovations available today. These features, combined with optionally available automated peripherals such as automatic gauging, tool life management, etc. will provide a complete production system from raw material to completed product with a minimum of operator attendance. Accuracy is of great importance.

- Ellison Machinery Company - Jungner CNC-Tool and Cutter Grinder Model PSA-600.

The justification for selecting this equipment is the PSA-600, an automatic precision grinding machine with grinding movements controlled in four directions by means of a microcomputer. The operator puts the tool to be ground in the machine, chooses a suitable program and inputs the required dimensions and data for the tool. The equipment performs the complete operation automatically.

- Concept Machine - Sodick Model EPOC 300 Wire-Cut EDM.

This machine was selected because the equipment incorporates some of the most advanced engineering features and highly advanced technologies along with superb ease of operation available today in Wire-Cut EDM. Accuracy is of the most importance.

- Anderson Machine Tool - B & S /Techmaster CNC 818.

The equipment was selected for its state-of-the-art technology in design, construction, precision and control. The machine offers certified precision capabilities, high productivity and complete computer numerical control. Programs or sections of programs which are regularly repeated are stored in the control as subroutines with variable parameters. The workpiece can be programmed directly on the machine and process parameters may be accessed during machining for display and alterations. Accuracy is of great importance.

## SECTION 12

### EQUIPMENT/MACHINERY ALTERNATIVES

If for any reason the preferred equipment as outlined will not be available (long lead time, excessive equipment cost increase, etc.) a similar machine of the same magnitude, but not of the same manufacture will be provided. This may include:

#### FLEX SHOP

- Concept Machine Tool Sales - CNC-Turning Tsugami Mercury.

This machine was selected as an alternative because of its high performance, accuracy, and similarity to the primary selection. This turning center embodies new concepts in automatic lathe design to assure greater accuracy and adaptability for diversified production, and is very cost comparable.

- Productivity Inc. - CNC-Automatic Lathe Index GS30.

This machine was selected as an alternative because of its flexible, economical production of small and large batches. Very high machining accuracy offered by the resolution of the numerical control. Accuracy is of great importance, and this equipment will meet or exceed all expectation requested by this investigation.

- Concept Machine Tool Sales - Landis IR CNC Cylindrical Grinder.

This machine was selected as an alternative because of its high performance and accuracy. The control system featuring fully integrated programmable controller, menu programming and permanently active diagnostics. The equipment performance is comparable to the Tschudin Model CNC Cylindramatic Plus in all aspects.

- Concept Machine - Sodick Model EPOC 300 Wire-cut EDM.

This machine was selected as an alternative because it incorporates some of the most advanced engineering features and technologies along with the most superb ease of operation available today in wire-cut EDM. The machine's capacity for a high degree of accuracy is also of great importance.

## MODEL SHOP/SHORT RUN SHOP

- Northwest Machine - Mazak Quick Turn ION ATC Turning and Milling Center.

This machine was selected as an alternative because it incorporates some of the most advanced engineering features and innovations available today. The machine can perform secondary machining operations in addition to turning, all in a single work piece set-up. It can be programmed by inexperienced operators. These features, combined with optionally available automated peripherals such as automatic gauging, robot loading, tool life management, etc. will provide a complete production system from raw material to completed product with a minimum of operator attendance. Accuracy is of great importance.

- Concept Machine Tool - Monarch Sidney C-10 Precision Universal Turning Machine.

This machine was selected as an alternate because of its high performance, accuracy and similarity to the primary selection. It incorporates the most sophisticated engineering and CNC technology available today. Accuracy is of great importance, and this equipment will meet or exceed all expectations required in this investigation.

- Duncan Company - Walter CNC Tool and Cutter Grinder Model Helitronic 30 CNC 3.

The justification for selecting this equipment for an alternate is based on its high performance, accuracy and its economical CNC programs. The special features of the control permit a new Dimension of Tool Grinding. The control prompts the operator with questions regarding tool dimensions and grinding procedures. Data entry is clear and easily understood. The equipment performance is very comparable to Jungner Model PSA-600 tool and cutter grinder.

- High-Tech Systems Inc. - Mitsubishi Wire-cut EDM Model DWC-70G (5)

This machine was selected as an alternate piece of equipment because it embodies sophisticated high-precision machining capability. The newly developed control unit and a host of new functions results in a quantum leap in user friendliness and reliability, achieving an astonishing level of machining precision. The equipment performance is very comparable to Sodick Model EPOC 300 in all aspects.

## SECTION 13

### MIS REQUIREMENTS/IMPROVEMENTS

The Model/Short Run Shop and Flexible Machining Area interface with Honeywell Manufacturing System (HMS), Process Management System (PMS), and Factory Data Collection (FDC) without modification to other systems hardware or software. These elements are discussed in further depth in Section 13 of the Project Overview.

Specific part dimensions will be captured by a Statistical Process Control (SPC) system within each process path or machine. Complete details of SPC are covered in the ITM Project 43 report.

## SECTION 14

### COST BENEFIT ANALYSIS/PROCEDURE

#### OVERVIEW

The Model/Short Run/Flex Shop is a combination of semi-dedicated cells and Model/Short Run Shop parts or jobs. The semi-dedicated cells were cells with part volumes too low to justify a fully dedicated cell. These cells, the 1 1/2" Bar and the Dither Spring, were incorporated in the Flex Shop to increase each cell's machine utilization. The Short Run parts, as defined in Section 14 of the Project Overview, were combined and analyzed with Model Shop jobs, which carry no time standards.

To calculate the savings, this work area was divided and analyzed in two major categories. The semi-dedicated cells in the Flex Shop was the first portion. The second analysis was the Model Shop and Short Run. The semi-dedicated cells savings were calculated on a part by part basis using actual standard hours as the cost driver. The Short Run and Model Shops, which includes the remaining hours not addressed by the dedicated cells (Sheetmetal, etc.), were categorized by major machining type. Each type was analyzed individually by Model Shop work and Short Run production work, due to different labor grades between Toolmakers and production operators.

#### MANUFACTURING SCHEDULE

The manufacturing schedule for the semi-dedicated cells used the marketing plan volume projections by product device where available. The remainder of the parts used the current years volumes and escalated those volumes by each related operations' revenue plan projections.

In evaluation of the Model/Short Run Shop, the manufacturing schedule was decided to show very little change, if any from the current years hours. It was assumed that the introduction of new products would balance out with the elimination of obsolete products.

#### ACTUAL STANDARD HOUR SAVINGS

The methodology for deriving the "As-Is" and "To-Be" actual standard hours for the semi-dedicated cells was followed as described in Section 14 of the Project Overview.

Total annual hours were used to establish the "As-Is" baseline for the Model/Short Run Shop. The total Short Run hours were identified and accumulated by the 40 X 360 matrix described in Section 14 of the Project Overview. The Model Shop hours were extrapolated from a ten week job load study. Each area was then sub-divided into four major machining or work types. The four types consisted of turning, milling/drilling, grinding, and miscellaneous. The total annual hours were then divided among the four work types using percentages derived from the 40 X 360 matrix. Three of the four work types were identified to show a possible cost savings. It was assumed the fourth, miscellaneous, would remain unchanged, showing no savings. A summary of this data is shown in Figure 8.5.

All three areas (milling, turning and grinding) based their actual hour savings on the introduction on new CNC machines. It was estimated that 60 percent of the total hours for each area could and would be absorbed by this new equipment. These factored hours were used as the "As-Is" baseline for each area in calculating the savings.

The "To-Be" baseline was established using the "As-Is" factored hours and applying a CNC improvement ratio. This improvement ratio is a direct comparison of conventional manually operated machines versus CNC machines. Some of the factors used to establish this ratio are shorter set-ups, better repeatability, simultaneous cutting and quicker tool changes. The turning and milling areas were estimated to have a 2.5 to 1 ratio while grinding should realize a 1.43 to 1 reduction. This ratio means 2.5 hours of conventional machining can be produced in only 1 hour using CNC equipment. All three estimates appear to be conservative after reviewing other Honeywell Divisions' results where CNC machines were introduced in similar manufacturing environments.

#### CAPITAL AND EXPENSE

The capital, recurring and non-recurring expense for the Model/Short Run, Dither Spring and 1 1/2" Bar are shown in Figures 14.2 through 14.4.

#### PROJECT SAVINGS AND CASH FLOWS

##### Model/Short Run Shop

The savings to be realized by the Model/Short Run Shop exceeds Honeywell's Military Avionics Division hurdle rate. The cell's cash flows are shown in Figure 14.5 with the assumption that capital is available per the implementation plan.

##### Dither Spring

The savings to be realized by the Dither Spring exceeds Honeywell's Military Avionics Division hurdle rate. The cell's cash flows are shown in Figure 14.6 with the assumption that capital is available per the implementation plan.

##### 1 1/2" Bar

The savings to be realized by the 1 1/2" Bar exceeds Honeywell's Military Avionics Division hurdle rate. The cell's cash flows are shown in Figure 14.7 with the assumption that capital is available per the implementation plan.

## COST BENEFIT ANALYSIS METHODOLOGY

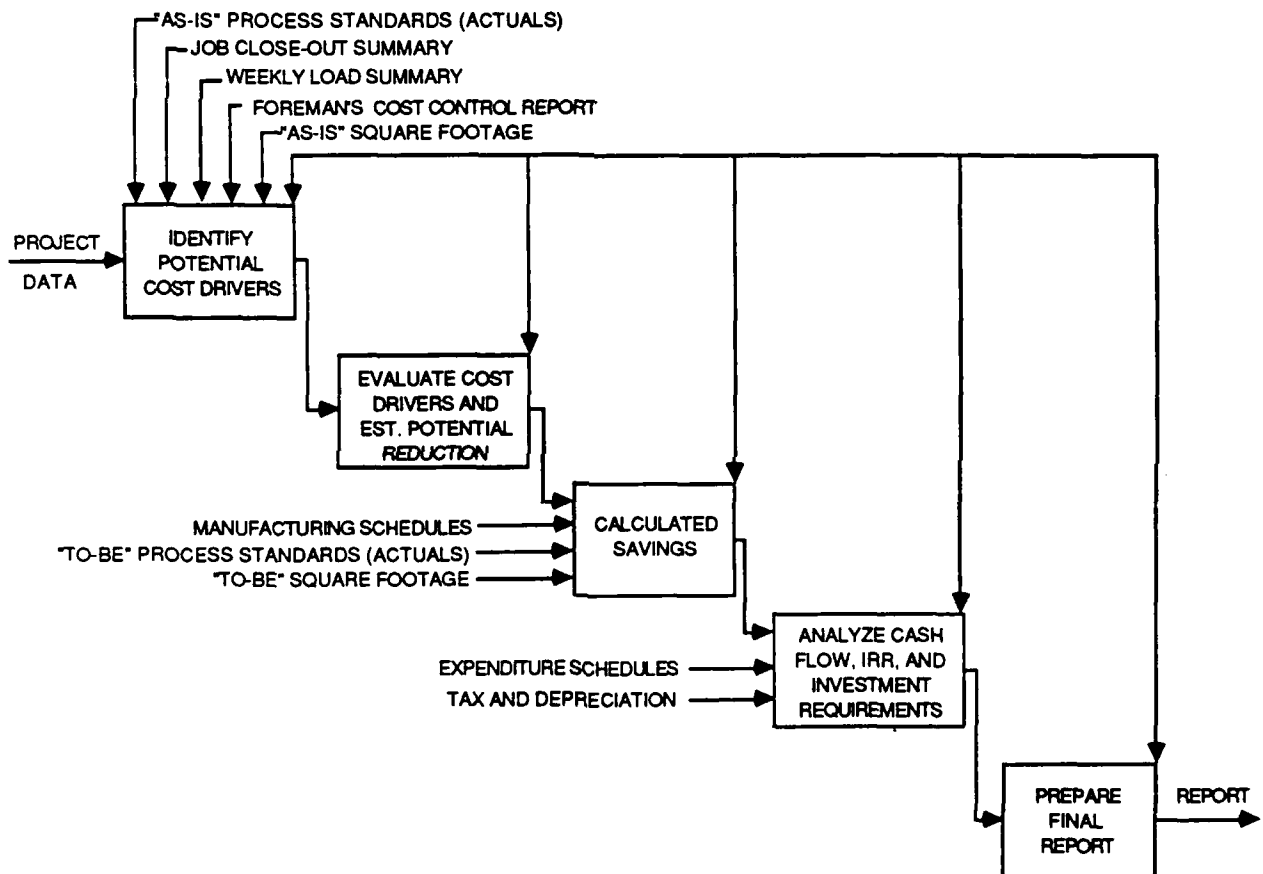


Figure 14.1 Model/Short Run/Flex Shop Cost Benefit Analysis Methodology

**SHORT RUN /MODEL SHOP CELL  
EXPENDITURE SCHEDULE**

Capitalization		EXPENSE COSTS		Year
Gross Cost	Date		Cost	Expended
<b>CAPITAL COSTS</b>				
<b>MACHINERY COSTS</b>				
.. CNC Lathe (2)	1989	\$168,809		1989
.. CNC Lathe	1990	\$335,105		1990
.. Bar Feed (2)	1989	\$40,892		1989
.. Bar Feed	1990	\$26,795		1990
.. CNC Machining Center (3)	1989	\$570,384		1989
.. Parts Shuttle (3)	1989	\$110,093		1989
.. CNC Three Axis Grinder	1990	\$169,539		1990
.. CNC Tool Grinder	1990	\$305,521		1990
		\$890,177		1989
		\$836,960		1990
		-----		
<b>TOTAL MACHINERY COSTS</b>		<b>\$1,727,137</b>		
<b>FURNITURE COSTS</b>				
.. Modular Benches	1989	\$44,270		1989
.. Storage Shelving	1989	\$6,699		1989
.. Storage Shelving	1990	\$2,680		1990
		\$50,969		1989
		\$2,680		1990
		-----		
<b>TOTAL FURNITURE COSTS</b>		<b>\$53,648</b>		
		\$941,145		1989
		\$839,640		1990
		-----		
<b>TOTAL CAPITAL COSTS</b>		<b>\$1,780,785</b>		
<b>NON-RECURRING EXPENSES</b>				
Area Preparation Labor (Hi)			\$16,800	1989
Area Preparation Labor (Hi)			\$5,600	1990
Training (Hi)			\$6,000	1989
Training (Hi)			\$4,000	1990
Post Processor Development Direct Lat			\$6,000	1989
Post Processor Development Direct Lat			\$4,000	1990
		\$28,800		1989
		\$13,600		1990
		-----		
<b>TOTAL NON-RECURRING COSTS</b>		<b>\$42,400</b>		
		\$1,823,185		
<b>RECURRING EXPENSES</b>				
* Annual Maintenance (Mechanical)			\$14,000	
* Annual Maintenance (Computer HW)			\$2,330	
* Annual Maintenance (Computer SW)			\$1,165	
			-----	
<b>TOTAL RECURRING</b>		<b>\$17,495</b>		
* Expense starts in year 2.				
** Net costs contain a 15% contingency				

Figure 14.2 Model/Short Run Shop Expenditure Schedule



**DITHER SPRING CELL  
EXPENDITURE SCHEDULE**

	Cost	Capitalization Date
<b>CAPITAL COSTS</b>		
<b>MACHINERY COSTS</b>		
** CNC (2) Axis Grinder	\$404,966	1990
** CNC Wire EDM (2)	\$509,105	1990
	-----	
TOTAL MACHINERY COSTS	\$914,071	
<b>FURNITURE COSTS</b>		
** Storage Cabinet	\$5,767	1990
	-----	
TOTAL FURNITURE COSTS	\$5,767	
	-----	
TOTAL CAPITAL COSTS	\$919,837	1990
<b>EXPENSE COSTS</b>		
<b>NON-RECURRING EXPENSES</b>		
Area Preparation Labor (HI)	\$52,900	1990
Training (HI)	\$4,000	1990
Post Processor Development Direct Labor	\$6,000	1990
	-----	
TOTAL NON-RECURRING COSTS	\$62,900	1990
 TOTAL CAPITAL + NON-RECURRING	 \$982,737	 1990
<b>RECURRING EXPENSES</b>		
* Annual Maintenance (Mechanical)	\$4,000	
* Annual Maintenance ( Computer HW)	\$233	
* Annual Maintenance (Computer SW)	\$233	
	-----	
TOTAL RECURRING	\$4,466	
<ul style="list-style-type: none"> <li>* Expense starts in year 2.</li> <li>** Costs contain a 15% contingency</li> </ul>		

Figure 14.3 Dither Spring Expenditure Schedule

**1.5 INCH BAR CELL  
EXPENDITURE SCHEDULE**

	Cost	Capitalization Date
<b>CAPITAL COSTS</b>		
<b>MACHINERY COSTS</b>		
** CNC Lathe (.5 inch capacity)	\$247,627	1989
** CNC Lathe (1.5 inch capacity) (3)	\$1,005,316	1989
** Bar feed (4)	\$99,142	1989
	-----	
SUB-TOTAL	\$1,352,084	
<b>FURNITURE COSTS</b>		
** Storage Shelving	\$11,592	1989
	-----	
SUB-TOTAL	\$11,592	
	-----	
TOTAL CAPITAL COSTS	\$1,363,676	1989
<b>EXPENSE COSTS</b>		
<b>NON-RECURRING EXPENSES</b>		
Area Preparation Labor (HI)	\$134,700	1989
Training (HI)	\$8,000	1989
Post Processor Development (D.L.)	\$10,000	1989
	-----	
TOTAL NON-RECURRING COSTS	\$152,700	1989
TOTAL CAPITAL + NON-RECURRING	\$1,516,376	
<b>RECURRING EXPENSES</b>		
* Annual Maintenance (Mechanical)	\$4,000	
* Annual Maintenance (Computer HW)	\$1,165	
* Annual Maintenance (Computer SW)	\$583	
	-----	
TOTAL RECURRING	\$5,748	
* Expense starts in year 2.		
** Costs contain a 15% contingency		

Figure 14.4 1 1/2" Bar Expenditure Schedule

TECH MOD PHASE 2  
PROJECT 44 -- SHORT RUN/MODEL SHOP CELL  
PROJECT CASH FLOW SUMMARY  
(\$000)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	TOTAL
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Capita	\$941.1	\$839.6	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$1,780.8
Non-Recurring Expenses	\$28.8	\$13.6	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$42.4
Recurring Expenses	\$0.0	\$0.0	\$9.0	\$17.5	\$17.5	\$17.5	\$17.5	\$17.5	\$17.5	\$17.5	\$17.5	\$17.5	\$166.5
Total Savings	\$0.0	\$545.0	\$918.8	\$963.9	\$1,010.2	\$1,058.6	\$1,111.4	\$1,164.0	\$1,217.4	\$1,270.8	\$1,324.1	\$399.0	\$10,985.2
Depreciation	\$91.1	\$248.3	\$283.3	\$227.5	\$182.9	\$147.2	\$118.7	\$113.8	\$120.9	\$120.9	\$90.9	\$35.1	\$1,780.8

Figure 14.5 Model/Short Run Shop Cash Flows

TECH MOD PHASE 2												
PROJECT 44 -- DITHER SPRING CELL												
PROJECT CASH FLOW SUMMARY												
(\$000)												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	TOTAL
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
Capital:	\$919.8	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$919.8
Non-Recurring Expenses	\$62.9	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$62.9
Recurring Expenses	\$0.0	\$0.0	\$4.5	\$4.5	\$4.5	\$4.5	\$4.5	\$4.5	\$4.5	\$4.5		\$35.7
Total Savings	\$646.8	\$560.7	\$457.9	\$412.1	\$452.2	\$409.5	\$414.2	\$414.9	\$413.6	\$411.8	\$411.8	\$5,005.4
Depreciation	\$91.6	\$165.0	\$132.1	\$105.8	\$84.7	\$67.9	\$54.4	\$62.1	\$62.1	\$62.1	\$32.0	\$919.8

Figure 14.6 Dither Spring Cash Flows

TECH MOD PHASE 2  
PROJECT 44 -- 1 1/2" BAR CELL  
PROJECT CASH FLOW SUMMARY  
(\$000)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	TOTAL
	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====	=====
Capital	\$1,363.7	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$1,363.7
Non-Recurring Expenses	\$152.7	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$152.7
Recurring Expenses	\$0.0	\$0.0	\$5.7	\$5.7	\$5.7	\$5.7	\$5.7	\$5.7	\$5.7	\$5.7	\$5.7	\$51.7
Total Savings	\$0.0	\$752.5	\$876.3	\$907.4	\$963.8	\$1,018.3	\$1,080.5	\$1,136.1	\$1,195.1	\$1,255.3	\$1,314.6	\$10,500.0
Depreciation	\$135.7	\$244.3	\$195.7	\$156.7	\$125.6	\$100.7	\$80.7	\$92.1	\$92.1	\$92.1	\$48.0	\$1,363.7

Figure 14.7 1 1/2" Bar Cash Flows

## SECTION 15

### IMPLEMENTATION PLAN

#### OVERALL IMPLEMENTATION PLAN

This detailed implementation plan describes the activities that are necessary to prepare the Fabrication Facility for the installation of the various phases of the Model/Short Run/Flex Shop. All phases of this plan are shown in Figure 15.1. The key elements driving this plan are discussed below.

#### BUILDING PREPARATION

Plant Engineering will prepare the plans for the construction area. This will involve the relocation of power, air, ventilation and the rearrangement of the machining centers and miscellaneous equipment.

#### PRODUCTION ENGINEERING

Production Engineering will develop the processes and methods for the parts assigned this cell. This includes preparing detailed instructions, tools, submittal of the tool requests and providing assistance in the ordering of the capital equipment. A Production Engineer will be assigned to direct, support and coordinate the move, and reprocessing of the various stages of this cell.

#### FACTORY MOVE COORDINATION

The activities for this move coordination will follow the following sequence:

- Surplus the excess equipment.
- Reprocess all the jobs assigned to the Model/Short Run/Flex Shop through Engineering Action Requests (EAR).
- Surplus any remaining unused equipment.
- Install and institute the Sheetmetal Cell.
- Relocate the Press Shop activities to share resources with the model shop and the Sheetmetal Cell.
- Assign Production Engineering liaison for support, coordination of the move and reprocessing.
- Assign an NC programming specialist to handle and coordinate the programming effort.

- Complete the conversion to HMS and the new factory scheduling, planning and job breakdown effort.
- Start a program to institute monthly team meetings, with factory personnel, to keep abreast on the move activity.
- Relocate the Kitamura's from the NC Milling area to their respective Flex Shop assignments. This move will allocate space for the Pallet Cell installation.
- Relocate the office areas to the layout configuration. This will free up space for the Model/Short Run/Flex Shop.
- Install the equipment for the Dither Spring, T-Bar, 1 1/2" Bar and Flex Shop Cells into its final configuration.
- Sequentially purchase the remaining CNC equipment planned for the Model/Short Run/Flex Shop. Each piece of equipment will follow a sequence of events consisting of the placement of the Purchase Order, preparation of the area, installing the equipment and an operator training program.
  - CNC lathe (chucker) (2).
  - CNC wire EDM.
  - Modular benches and accessories.
  - Pallet shuttle table (2).
  - CNC ID and OD grinder.
  - CNC surface grinder.
  - CNC tool grinder.
  - CNC lathes (2).
- Relocate the benches and remaining Model Shop equipment to the designated areas.

# MODEL/SHORT RUN/FLEX SHOP CELL IMPLEMENTATION PLAN

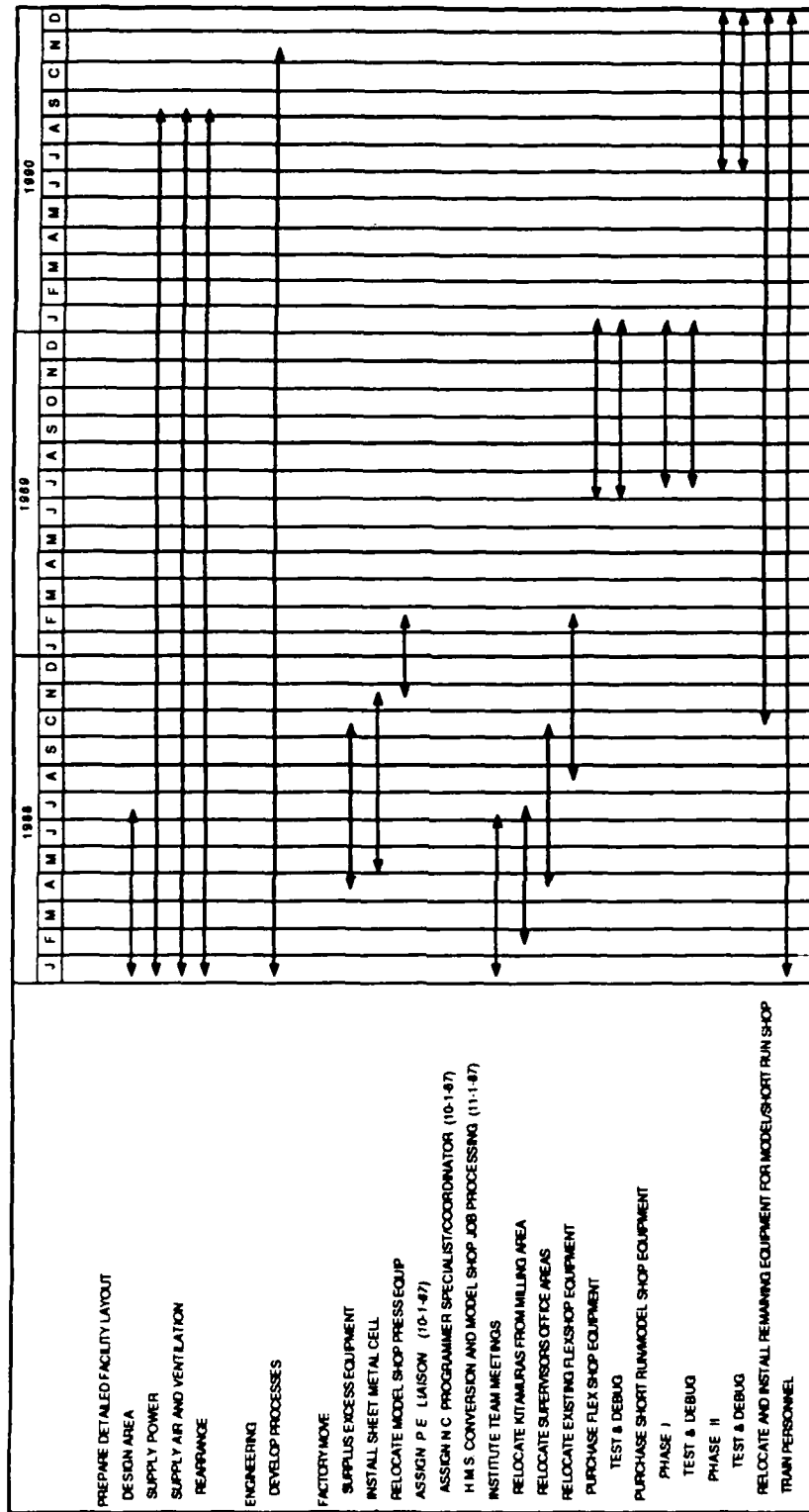


Figure 15.1 Model/Short Run/Flex Shop Implementation Plan



## SECTION 16

### PROBLEMS ENCOUNTERED AND HOW RESOLVED

**PROBLEMS:** One of the preliminary design concepts for Project 44 was to purchase a CNC Jig Grinder to do the header magnet assembly and share resources with ITM Project 51/52 and the Model Shop. Due to the high costs of this piece of equipment, the project could not justify a return on this investment.

**SOLUTION:** Continue to monitor the capital list every six months for a piece of equipment that will serve our needs and also our cost parameters. We will also remain in contact with the vendors in case any new piece of equipment surfaces or the costs go down.

## SECTION 17

### AREAS FOR FUTURE CONCERNS/DEVELOPMENTS

#### FUTURE CONCERNS

##### Forecast Volumes

The equipment utilization and return on investment are based on the current projected volumes and shop loads. If the volumes and loads on the group of parts identified for this cell decrease, the entire context of the cell would have to be rescoped.

##### Hand Chucker Volume

If there is a modest change upward in the volumes or loads for the Model/Short Run/Flex Shop, it would justify changing the Hardinge hand chuckers to CNC equipment. The loads will be monitored through the capacity requirements planning (CRP) module of HMS to initiate an investigation of capital investment of CNC replacement machines.

##### Jig Bore Work Load

Any moderate increases in volume or work load on the Dixie manual jig bore would justify changing to a horizontal machining center.

#### FUTURE DEVELOPMENTS

##### Working Model

A working scale model (1/4" scale) will be built of the Model/Short Run/Flex Shop under a burden project to confirm the material flow in the area.

##### Future Dedicated Cell

Due to the variable nature of the parts from our customer, the style or configuration of the parts are constantly changing. The matrix population will be confirmed and the Flex Shop flow paths will be readdressed for potential dedicated cells prior to implementing the Model/Short Run/Flex Shop.

# **PROJECT 44**

## **NC PROGRAMMING**

### **SECTION 1**

#### **INTRODUCTION**

A major support requirement has been created in Project 44 by the proposed use of 41 Computer Numerically Controlled (CNC) machines. This support requirement is divided into two areas:

- 1) The Numerical Control (NC) programming function.
- 2) The transmission of the created machine control data to the CNC machine tool.

To fulfill this support requirement, the use of a computer aided design and manufacturing system (CAD/CAM) integrated with a Distributed Numerical Control system (DNC) is proposed in this document.

The benefits of this system will be realized in all work cells and shop floor areas through reduced cost in new machine conversions, engineering change orders, updates, model costs and tool costs.

## SECTION 2

### PROJECT PURPOSE/OVERVIEW

The objective of this project segment is to provide a NC programming system that will support the CNC requirements generated in Project 44 more efficiently than if the current method were used.

A CAD/CAM system integrated with a DNC system will be used to realize a reduction in programming cost, flat format generation costs, prove-out costs and also the system will eliminate paper tape.

## SECTION 3

### TECHNICAL APPROACH

Originally, Phase 2 of this project was directed toward a NC programming system to support CNC turning and CNC machining centers only. The Phase 1 report assumed we would be eliminating the punch press area, however, changes in the current and projected sheetmetal loads from Honeywell's Test System and Logistics Operations caused a reversal of this plan. Even though a considerable portion of this project segment was completed when this additional requirement was added, the final "To-Be" NC programming and support system will support all CNC requirements of Project 44.

#### CNC TURNING MACHINE AND CNC MACHINING CENTER SUPPORT

The technical approach to Phase 2 of this project began with the establishment of a project team. This team was comprised of NC programmers and production engineers from Honeywell's Military Avionics Fabrication Facility (Fab Fac). The NC programmers represented experience in manual programming and the use of the APT programming language. The production engineers, certified in NC programming through the Association for Integrated Manufacturing, represented experience in manual programming and the use of the APT and Compact II programming languages.

The following describes the approach taken by the team to develop an NC programming support system:

A current process analysis was conducted in which the team analyzed the steps currently being taken to create a CNC machine readable part program along with the medium used to load that data into the CNC machine tool. Also addressed was the notification by the present supplier that the time-sharing service currently being used would be discontinued.

The above exercise established the "As-Is" conditions and defined both areas as candidates for improvement.

Based on the number, type and the location configuration of the CNC machine tools originally proposed in Project 44, the design requirements were established. With these requirements defined, a study was then made of available systems (programming and distribution) that utilized the latest proven technology in today's market. This involved the attendance of vendor shows, seminars and utilizing data from vendor literature.

Using the results of the above action, quotes were requested of and received for various NC programming and DNC systems. Then an evaluation criteria matrix was created for each system. These matrixes were used to select a final vendor.

## CNC PUNCH PRESS SUPPORT

The approach taken to address the additional requirement for CNC punch press support began as a combined effort involving design and Production Engineering. It was noted that the majority of sheetmetal product design originates on Design Engineering's CADD system and therefore the data base may be used in the process of producing a NC program. As a result, a study was made of sheetmetal programming systems in the industry's market that would be compatible with Honeywell's current CADD system and fulfill the requirements established by the Sheetmetal Cell. This was accomplished through vendor contact and seminar attendance by design and Production Engineering.

One system was found to meet all requirements. A quote was requested and received. Based on the chosen vendor proposals, the final layout drawings were prepared and a implementation schedule determined.

## SECTION 4

### "AS-IS" PROCESS

At this time, NC programming support is required at Honeywell's Military Avionics Fabrication Facility (Fab Fac) for CNC vertical machining centers, NC horizontal machining centers, CNC turning machines and a NC punch press.

The programming process used for NC punch press machines is a manual process. For NC or CNC machining centers and CNC turning machines, an APT time-sharing system is currently used. However, this service is being discontinued by the supplier, therefore, the programming process defined to support these machines will also be a manual one.

#### NC PROGRAMS

The processes used to create NC machine readable programs are as follows (refer to Figure 4.1):

##### Turning Machines and Machining Centers

- NC programmer receives three documents of information:
  1. A request for a NC program.
  2. A part print.
  3. A production process manufacturing detail. This document is prepared by a Production Engineer and defines:
    - Which machine tool is to be used.
    - The sequence in which the part is to be machined.
    - The tools to be used (fixtures and cutting tools).
    - The cutting feeds and speeds used to machine the part.
- NC programmer prepares a hand written, machine readable manuscript block by block per the manufacturing detail. This involves:
  1. Calculating X,Y, and Z locations.
  2. Calculating tangency points.
  3. Calculating tool offsets.
  4. Choosing correct machine preparatory and miscellaneous function codes.
  5. The marking up of a part print to show tool path for later reference.
- NC programmer inputs the program into a computer processing unit via a keyboard and compares input to the handwritten manuscript for errors.
- NC programmer plots the program to detect tool path errors.

## NC PROGRAMMING CELL -- AS IS IDEF0 CHART

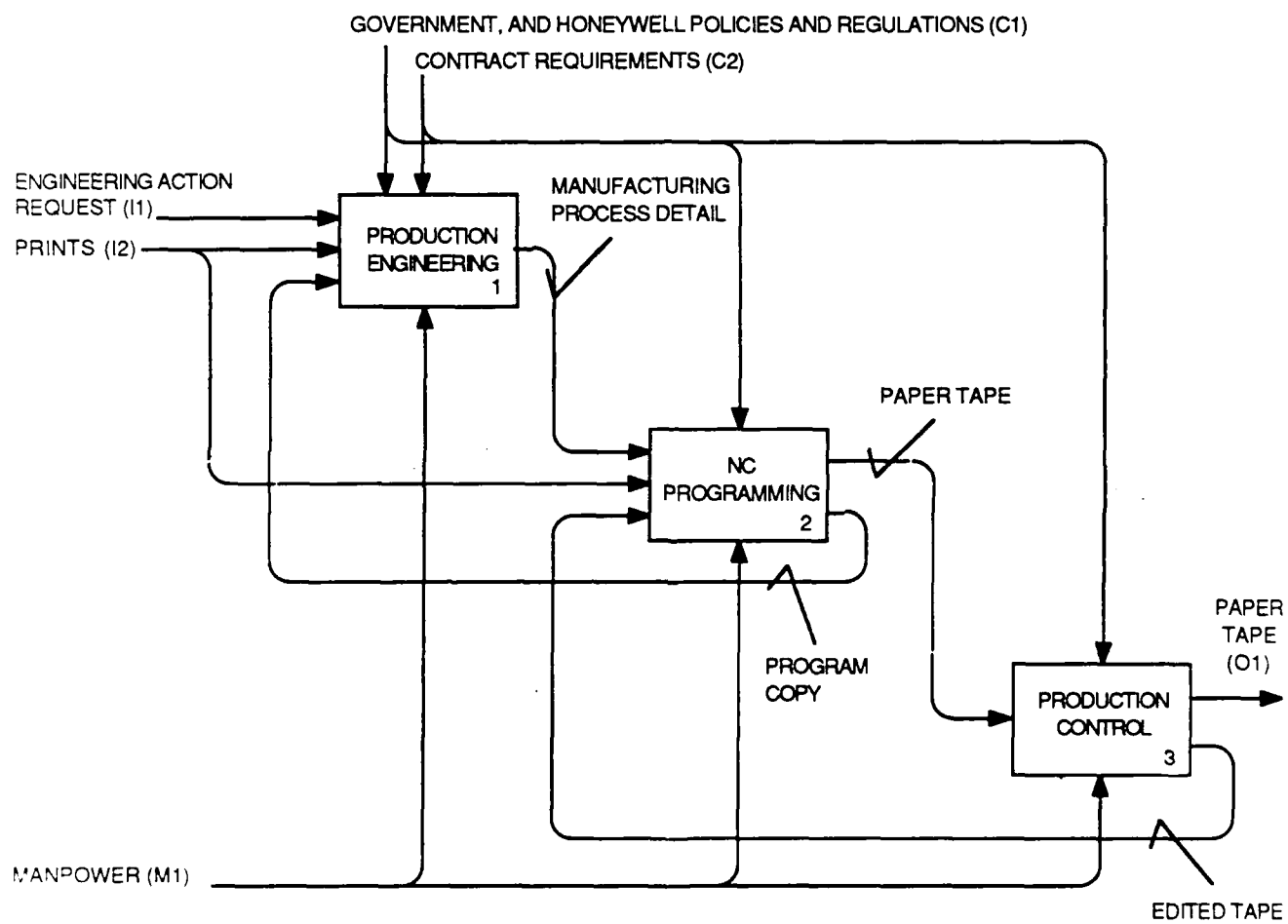


Figure 4.1 "As-Is" NC Programming Workflow Diagram



- NC programmer stores the program on a floppy disk and creates a back-up disk. Both disks are filed.

#### NC Punch Press

- Using a part print as reference, a tool designer creates a flat format drawing. This involves:
  1. Calculating bend allowances.
  2. Calculating all X and Y coordinates.
  3. Determining the blank size.
  4. Punch selection.
- NC programmer prepares a handwritten, machine readable program per the flat format drawing.
- NC programmer inputs the program into a computer processing unit via a keyboard and compares input to the handwritten manuscript for errors.
- NC programmer plots the program to detect tool path errors.
- NC programmer stores the program on a floppy disk and creates a back-up disk. Both disks are filed.

#### TAPE PREPARATION

The medium currently used to load the machine readable program into the NC or CNC machine tool's control is a punched paper tape. The preparation of this paper tape is completed as follows:

- Production Engineering analyst receives a request from Production Control for a machine control tape.
- Production Engineering analyst locates filed disk which contains the tape program requests.
- Production Engineering analyst loads a disk in a computer processing unit and outputs a tape through a tape punching unit.
- Production Engineering analyst sends the punched tape to Production Control.
- Production Control delivers the tape to the shop floor.
- Machine tool operator loads the program into the machine tool's control unit via the tape reader.

## SHOP FLOOR EDITING

Due to programming errors, fixturing incompatibility, and tool path and metal removal optimization, editing of the program may be necessary. The majority of editing occurs when a program is used for the first time or a major revision has been made to an existing program.

Editing at the machine tool is performed by an NC programmer. After the necessary edits have been made, the original and back-up files stored on floppy disks must be updated. This updating is accomplished by one of two methods:

- A copy of the edited program is output from the machine tool's memory via a portable tape punching unit. The program is then input into the NC programming departments computer processing unit through its tape reader. The original and back-up disk files are replaced by the edited program.
- If the machine tool is incapable of punched tape output, the changes are recorded manually. The noted changes are then made to the original and back-up files through keyboard input to the NC department's computer processing unit.

## FACILITY

The layout of the current NC Programming area located within the Fabrication Facility is defined in Figure 4.2. The hardware used to create a machine readable tape is shown and consists of a micro-processor with three work stations and one time-sharing terminal.

## DISADVANTAGES OF CURRENT PROCESS

The principle cost drivers in the NC programming process are the manual tasks that must be accomplished. These manual tasks are as follows:

- NC programmer tasks:
  1. Performs many trigonometry and arithmetical calculations.
  2. Writes program in correct syntax and select the correct machine codes. The codes may vary between machine tool types.
  3. Marks-up part print for reference.
  4. Inputs all data via keyboard.
  5. Physically carries edited programs from the shop floor to the NC programming department.
  6. Locates filed disks and re-file.
- Tool designer tasks:
  1. Draws layout in flat sheet format.
  2. Calculates bend allowances.
  3. Selects punches.
  4. Determines blank size.

- Production Engineering analyst tasks:
  1. Locate and re-file disks.
  2. Load disks and punch paper tapes.
  3. Place punched tape in container and deliver it to Production Control.
- The Production Control planner carries the punch tape to the shop floor.
- The machine tool operator manually loads the punched tape into the tape reader.

## NC PROGRAMMING CELL OFFICE FLOOR LAYOUT

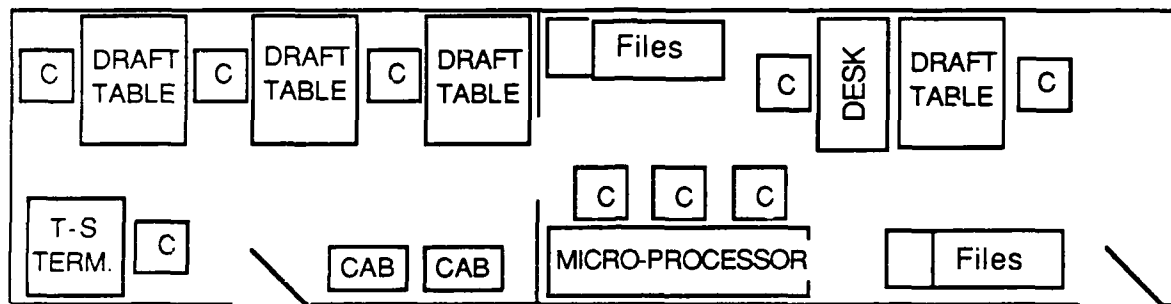


Figure 4.2 "As-Is" NC Programming Office Floor Layout

## SECTION 5

### "TO-BE" PROCESS

The proposed NC programming support system is an in-house system located within Honeywell's Military Avionics Division's Fabrication Facility. This system utilizes the latest proven technology in the manufacturing industry. It consists of the integration of CADD/CAM and DNC.

#### NC PROGRAMS

With the NC programming system, the process to produce a machine control file for all CNC machine tools (refer to Figure 5.1) proposed in Project 44 except for the CNC punch press is as follows:

- A NC programmer receives:
  1. A request for a NC program.
  2. A part print.
  3. A production process manufacturing detail.
- The NC programming CADD/CAM system will then execute the following for the programmer based on input commands:
  1. Accepts data from design engineering's CADD/CAM system or accepts input from the NC programmer using the part drawings as a reference.
  2. Graphically shows the tool path in color as the source program is created.
  3. Handles all math and trigonometry calculations.
  4. Creates a cutter location (CL) file.
  5. Post processes the CL file and generates a machine control file for the CNC machine tool specified.
  6. Stores the machine control data on the Direct Numerical Control (DNC) file server.
  7. Produces a printed copy of the machine control file.
- The NC programmer sends a printed copy of the machine control file to Production Engineering.

The process to produce a machine control file for the CNC punch press using the proposed system is as follows:

- A tool designer receives:
  1. A request for a NC program.
  2. A part print.

## NC PROGRAMMING CELL -- TO BE IDEF0 CHART

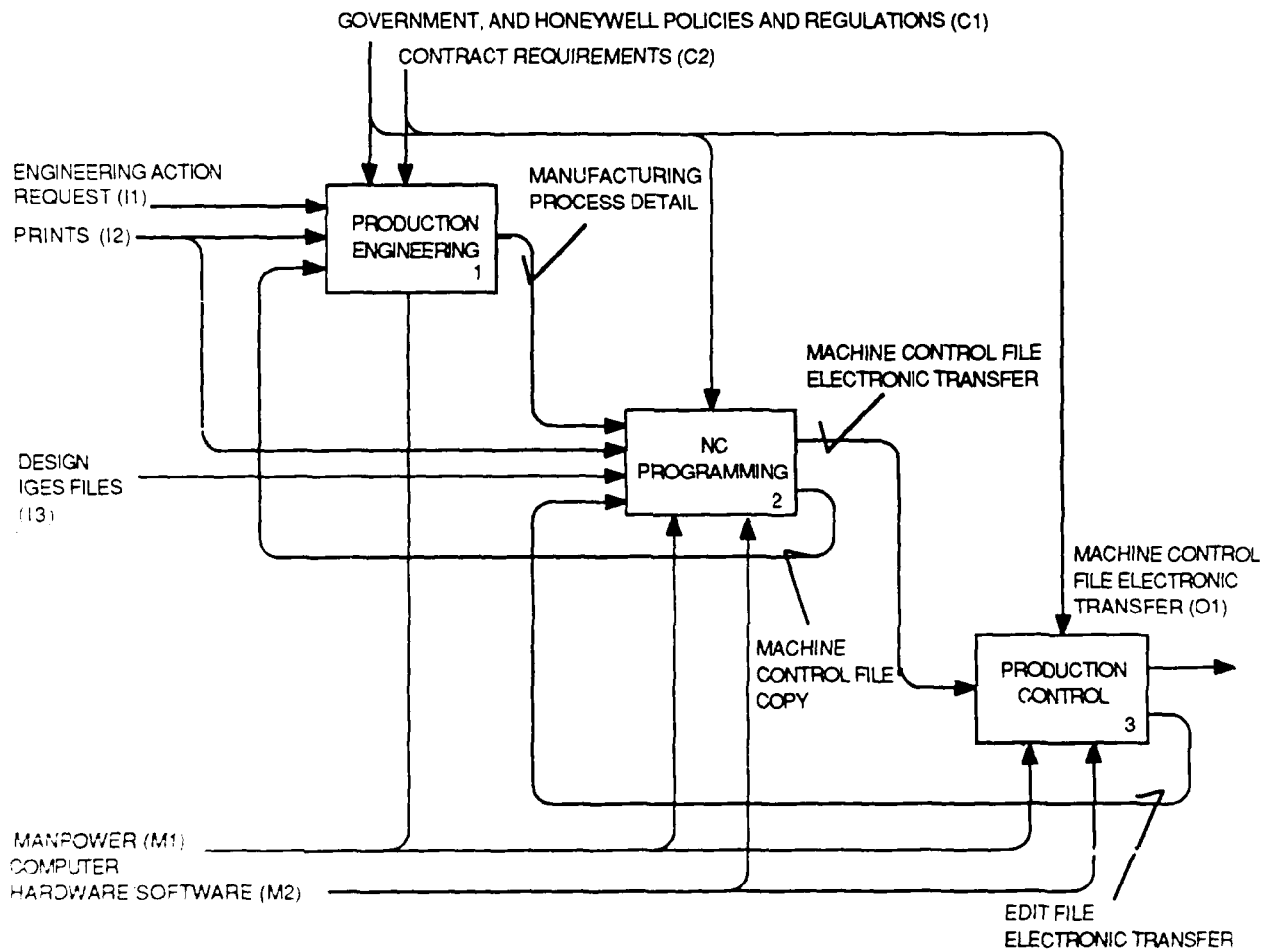


Figure 5.1 "To-Be" NC Programming Workflow Diagram

- The Sheetmetal CADD/CAM System will then execute the following for the tool designer based on input commands:
  1. Accepts data from design engineering's CADD/CAM system or accepts input from the tool designer using the part drawing as a reference.
  2. Unfolds the part into a flat-sheet format.
  3. Calculates all bend allowances and corresponding geometry.
  4. Selects tools to be used.
  5. Graphically shows the tool path in color.
  6. Creates a CL file.
  7. Post processes the CL file and generates a machine control file for the CNC punch press specified.
  8. Generates a flat sheet format drawing.
  9. Produces a printed copy of the machine control file.
  10. Stores the control file program on the DNC file server.
- Tool designer manually routes a hard copy of the flat sheet format drawing and a printed copy of the machine control file to Production Engineering.
- Tool designer manually routes a flat sheet format drawing to document control.

#### DIRECT NUMERICAL CONTROL

As discussed earlier in this section, the networking of the NC programming system and the DNC system allows the machine control file to reside on the DNC file server. This capability allows the machine tool operator to access and down load the machine control file from the DNC file server to the CNC machine tool. This is accomplished through the use of a DNC terminal located within each work cell.

#### SHOP FLOOR EDITING

Shop floor editing will be performed by a NC programmer using the DNC terminal located within the work cell. The system provides full editing and graphic plotting capabilities. When the required edits are complete, the edited file is electronically transmitted to the DNC file server.

#### FACILITY

Figure 5.2 shows an overview of the "To-Be" facility layout. The CAD/CAM System used for flat format drawings and punch press machine control file generation is located in the tool design area. The file server and the CAD/CAM system used to produce machine control files for all CNC machines, except the punch press, are located in the NC Programming Area. Multi-tasking terminals are centrally located within each cell or shop area.

# NC PROGRAMMING CELL FACILITY LAYOUT -- TO BE

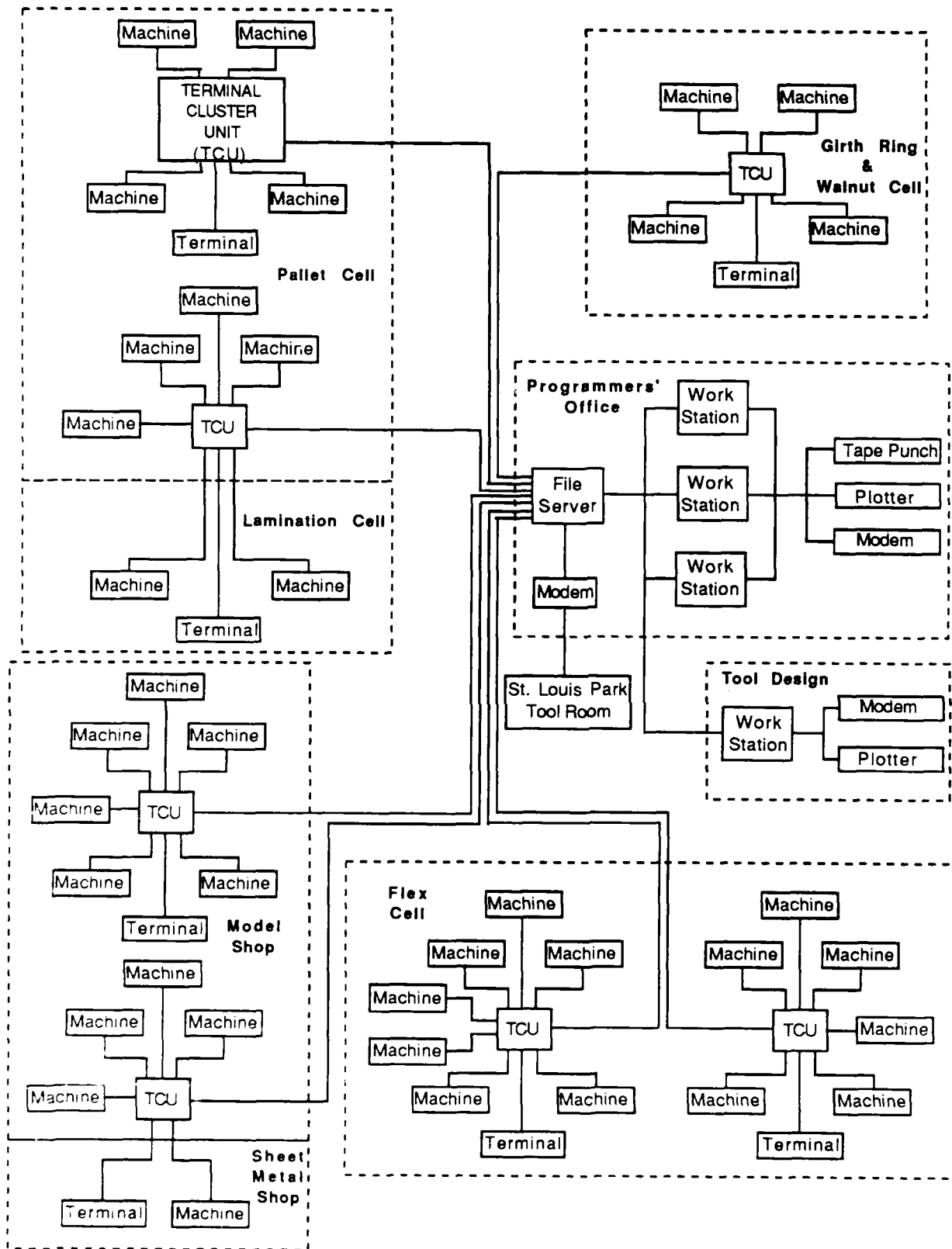


Figure 5.2 "To-Be" NC Programming Floor Layout Schematic



#### ADVANTAGES OF THE PROPOSED PROCESS

An advantage of the proposed NC Programming Support System is the elimination of the manual tasks performed by the NC programmer, tool designer, Production Engineering analyst, Production Control planner and machine tool operator. The system will also generate machine control files that are more efficient and with less errors than if a manual process were used. These advantages will be realized in all machining cells and shop floor areas utilizing CNC machines through reduced cost in new machine conversions, Engineering Change Orders(ECO), updates, model costs and tool costs.

## SECTION 6

### PROJECT ASSUMPTIONS

The following ground rules and assumptions were made in the analysis of the NC programming support system:

- The type, location and number of CNC machines will not change from the final Project 44 overall plant layout.
- The implementation of the DNC systems is dependent on the implementation of each CNC machine.
- The floor space and capital required for this system will be made available when this phase of Project 44 is implemented.
- The implementation of the Sheetmetal CAD/CAM System is dependent on the approval of a capital appropriation request by Honeywell management before October 1987.
- When the title of NC Programmer is referenced in this segment, the task being performed may also be completed by a Production Engineer.

## SECTION 7

### GROUP TECHNOLOGY CODING SYSTEM ANALYSIS

No group technology coding system is proposed for this segment.

## SECTION 8

### PRELIMINARY/FINAL DESIGN AND FINDINGS

The approach to the development of the final design has been described in the technical approach section (Section 3) of this document.

#### PRELIMINARY DESIGN

From the beginning of this project, the objective of efficiency and cost effectively supporting the requirements of the CNC machines proposed in Project 44 was established. However, at the above time, the final designs for the work cells and other shop areas were not complete. Therefore, only the following general requirements could be established:

##### NC Programming System

- In-house system.
- 2 1/2 axis capabilities.
- Interface with design engineerings CADD system (Computervision, CADDs 4x).
- Generalized post processors.
- Input simplicity.
- BCL generating (Binary Cutter Location).
- Interactive graphics.
- Vendor technical support.
- Multiple machine-type capabilities.
- Availability of training.
- Availability of maintenance contract.
- 3 user capacity.
- DNC compatibility.
- Plotting capability.
- Tape punching capability.

##### DNC System

- Support 30 CNC machine tools configured within 5 work cells, a production area, and a tool room area.
- Expandability.
- Storage capacity. Must be capable of storing machine control files for existing and future processes.
- BCL compatible.
- User training.
- Shop floor editing.

Using the selected vendors products and the DNC overall requirements, a preliminary design was developed (reference Figure 8.1).

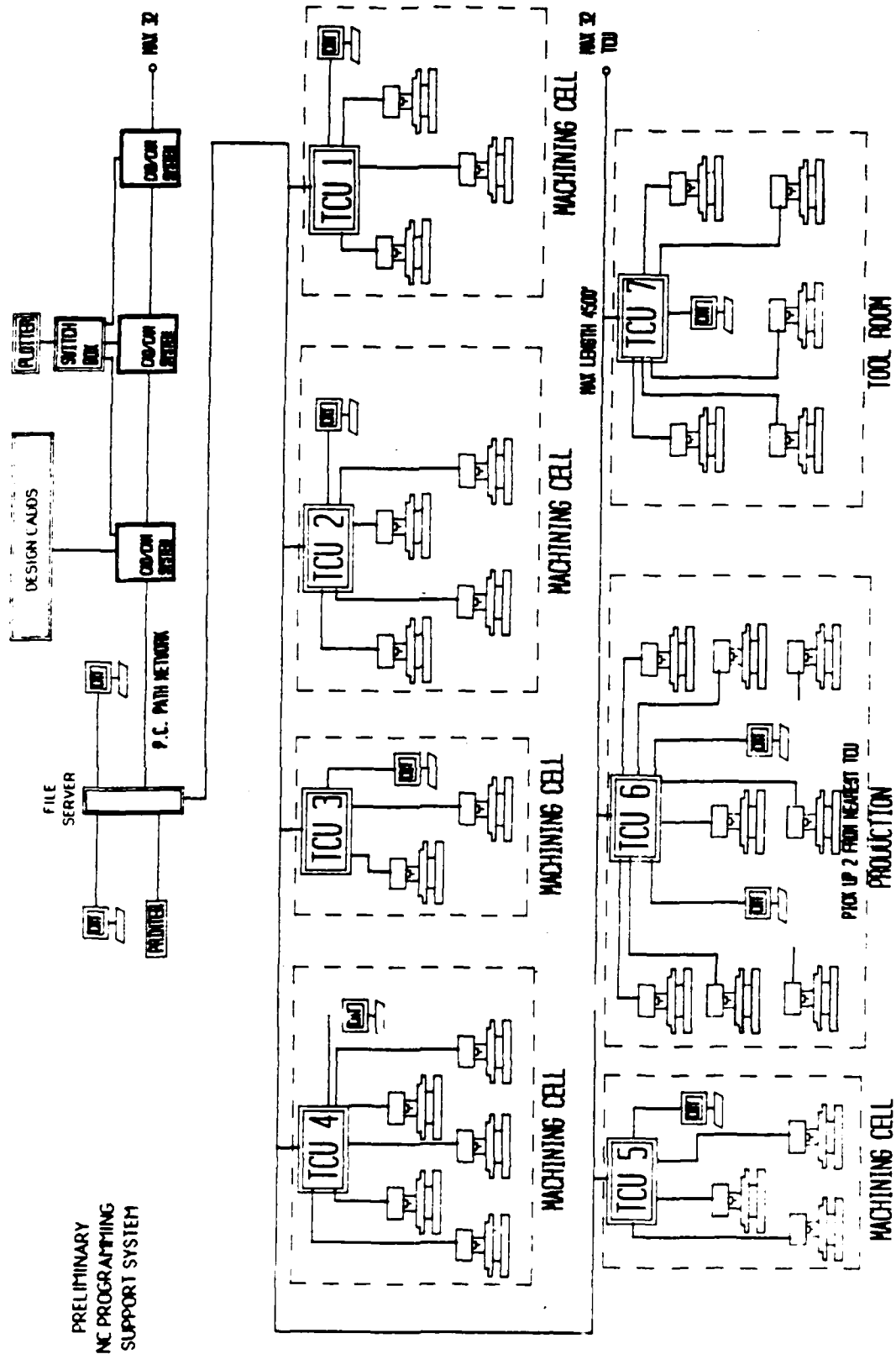


Figure 8.1 Preliminary NC Programming Support System

## FINAL DESIGN

As the Fabrication Facility floor layout matured to it's final design, the following revisions affected the NC programming and DNC support systems design:

- Addition of the Sheetmetal Cell.
- Addition of CNC machines located in Honeywell's St. Louis Park facility.
- The total number of CNC machine tools to be supported increased from 30 to 41.

To support these additional requirements, the following revisions were made to the NC programming and DNC systems design:

- Addition of the sheetmetal CAD/CAM system.
- Addition of a satellite DNC terminal at Honeywell's St. Louis Park facility.
- Additional terminal cluster units (TCU) and shop floor terminals were incorporated.

With all the necessary final requirements established, the following occurred:

- A final design was developed (reference Figure 8.2). The interface of Design Engineerings' CADD System and the Fabrication Facilities CAD/CAM Systems is made through IGES. This interface allows the down loading of a design data base file. The four CAD/CAM Systems and the file server are networked allowing the down loading of machine control files. The stored machine control files are accessed by the appropriate machine tool. This access is accomplished through a RS232 interface between the file server, a multi-tasking terminal and a CNC machine allowing bi-directional communication.
- The NC programming and tool design departments floor layouts were finalized. This was done within the limits dictated by the preliminary over-all Fab Fac layout (reference Figure 8.3).
- The terminal cluster units (TCU) which control the flow of data between the machine and file server are located within each work cell or manufacturing area. In determining this location, maintenance accessibility and ease of installation were the primary objectives.
- The DNC terminals were centrally located within each work cell or manufacturing area for operator accessibility (reference Figures 8.4 - 8.9).

## NC PROGRAMMING CELL FACILITY LAYOUT -- TO BE

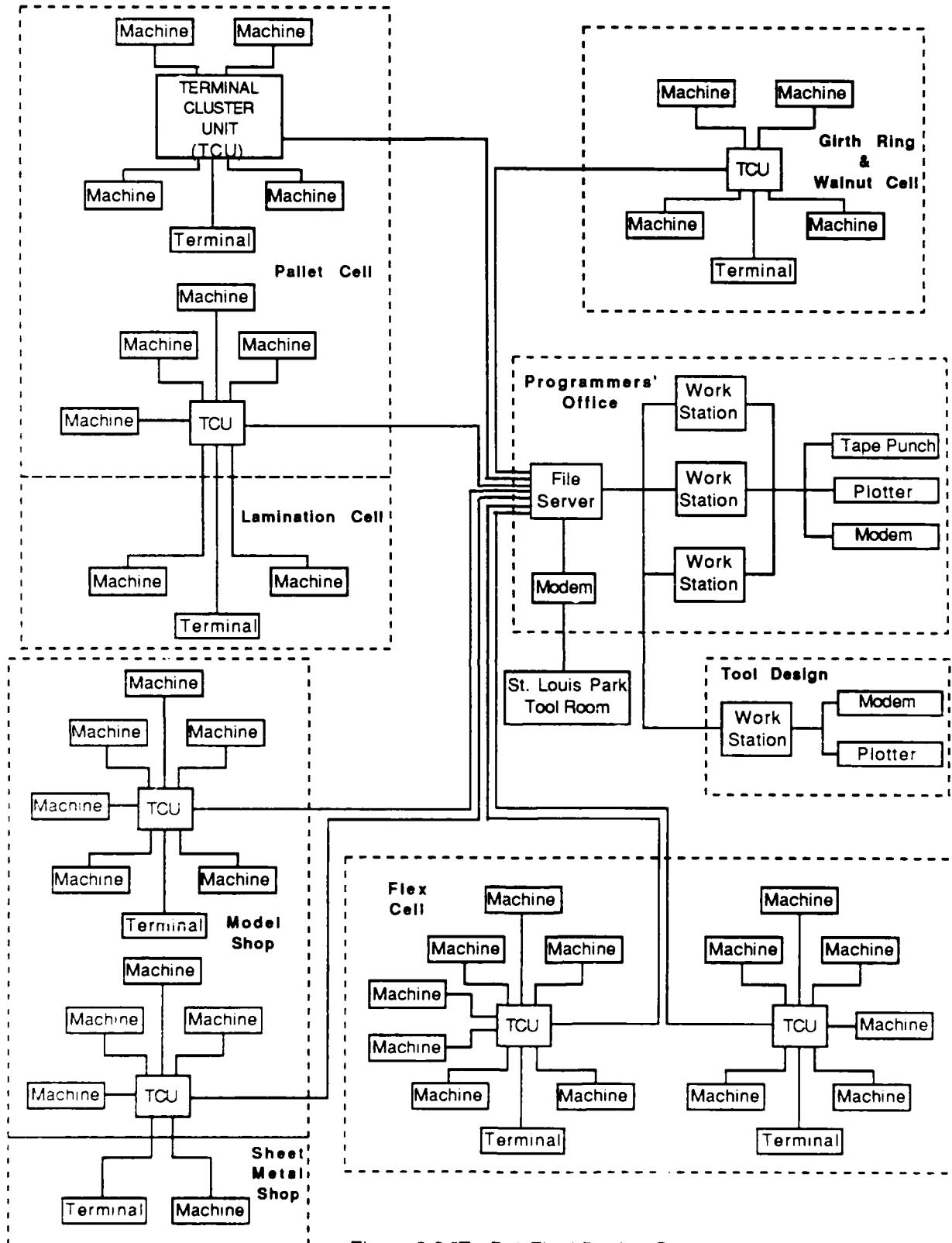


Figure 8.2 "To-Be" Final Design Overview

# NC PROGRAMMING CELL OFFICE FLOOR LAYOUT

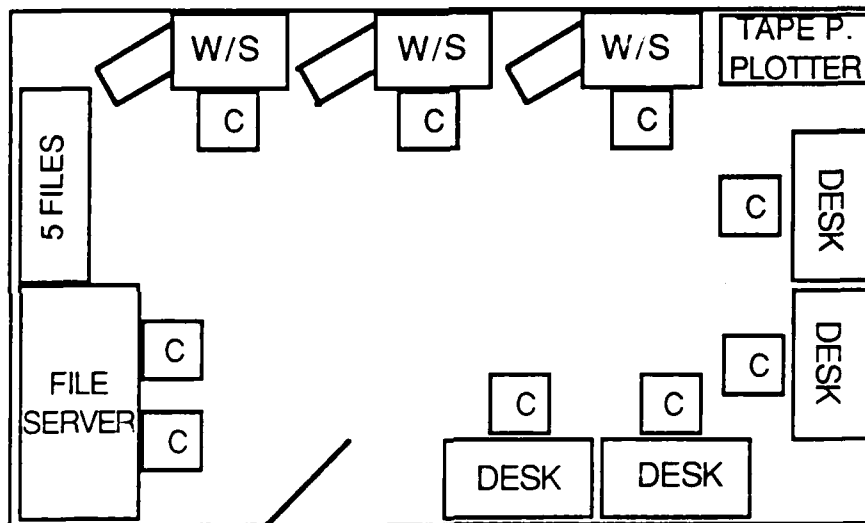


Figure 8.3 "To-Be" NC Programming Office Floor Layout



## PALLET CELL DNC TERMINAL LOCATION

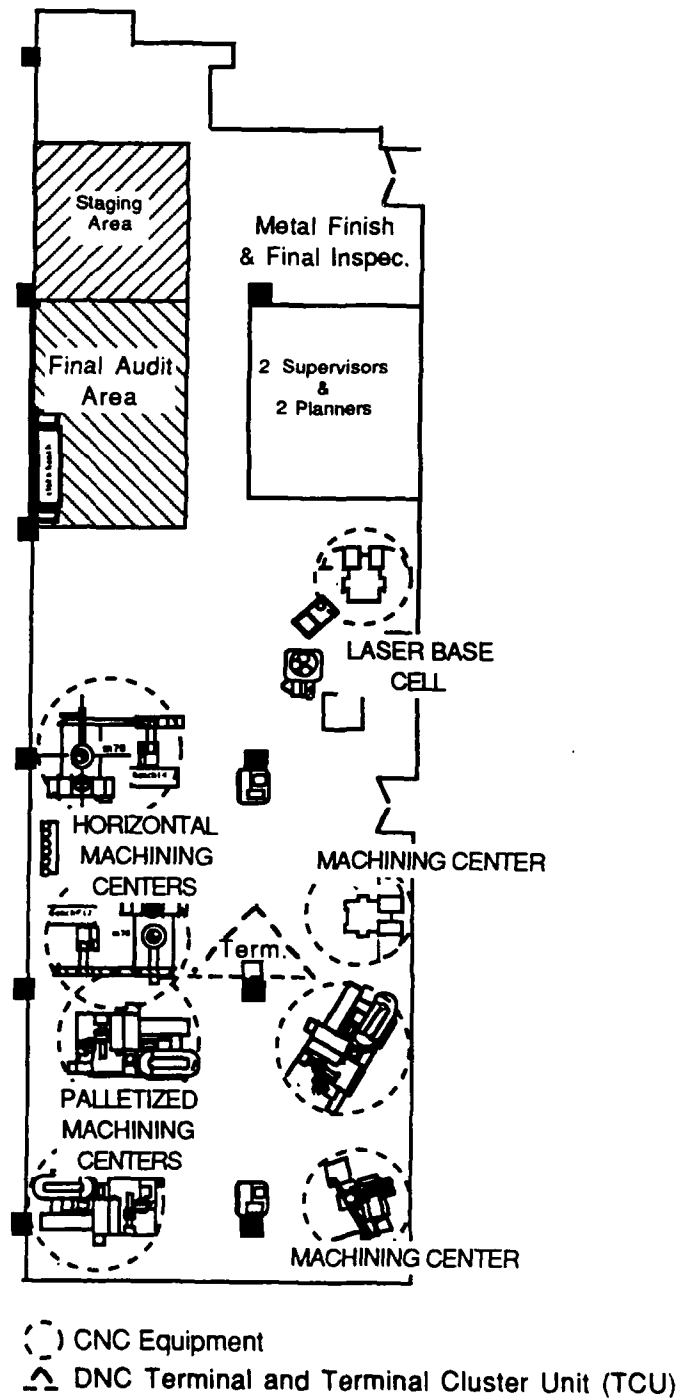
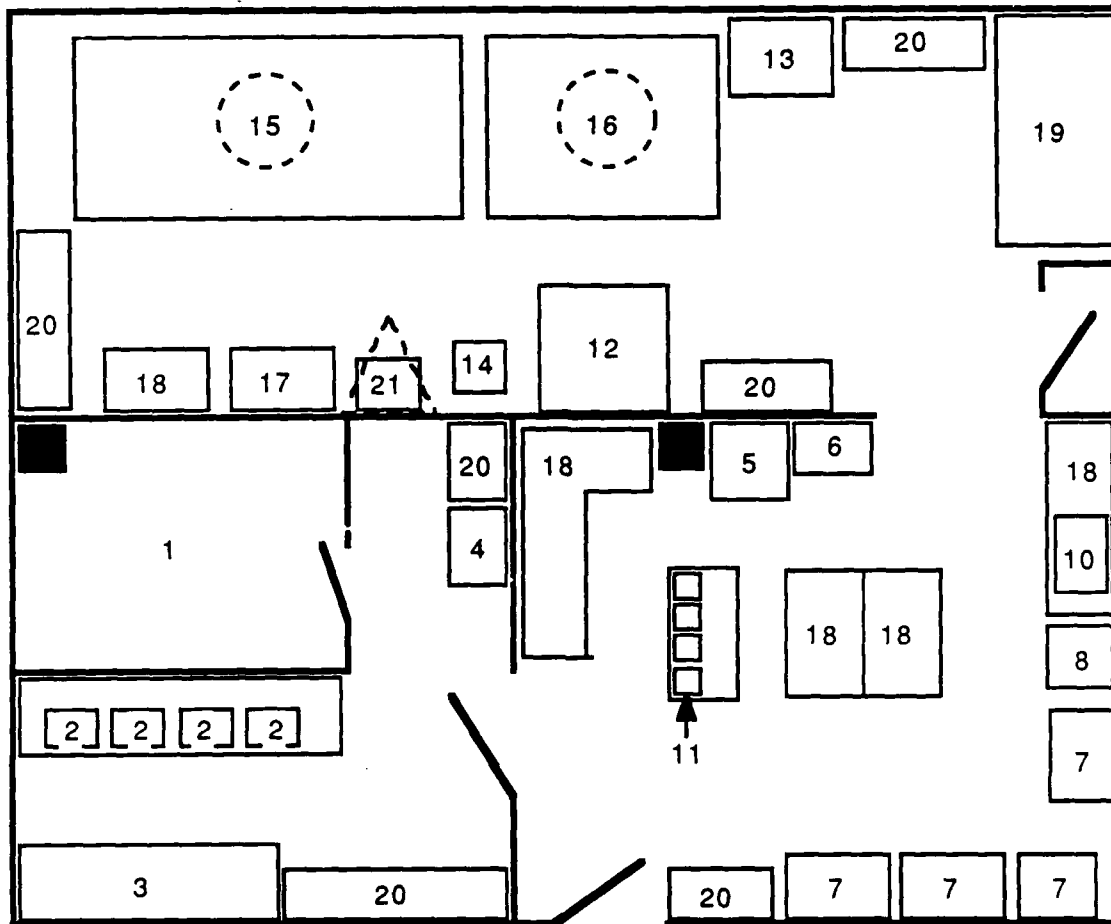


Figure 8.4 "To-Be" Pallet Cell DNC Terminal Location

## LAMINATION CELL DNC TERMINAL LOCATION



- |                              |                                 |
|------------------------------|---------------------------------|
| 1. Soda Blast vacuum         | 12. Lapping Machine             |
| 2. SS White Soda Blast Units | 13. Ultra-sonic Cleaner         |
| 3. Sink & Drain              | 14. Center Lap                  |
| 4. Dry Ice Freezer           | 15. Internal Grinder (Bryant)   |
| 5. Dryer Oven                | 16. External Grinder (Tschudin) |
| 6. Bottled Gas               | 17. Lapping Machine             |
| 7. Ovens                     | 18. Bench                       |
| 8. Vented Hoods For Solvents | 19. Inspection                  |
| 10. Burr Brushing Machine    | 20. Shelving                    |
| 11. Hot Presses              | 21. Terminal                    |

 CNC Equipment

 DNC Terminal and Terminal Cluster Unit (TCU)

Figure 8.5 "To-Be" Lamination Cell DNC Terminal Location

# WALNUT & GIRTH RING CELLS DNC TERMINAL LOCATION

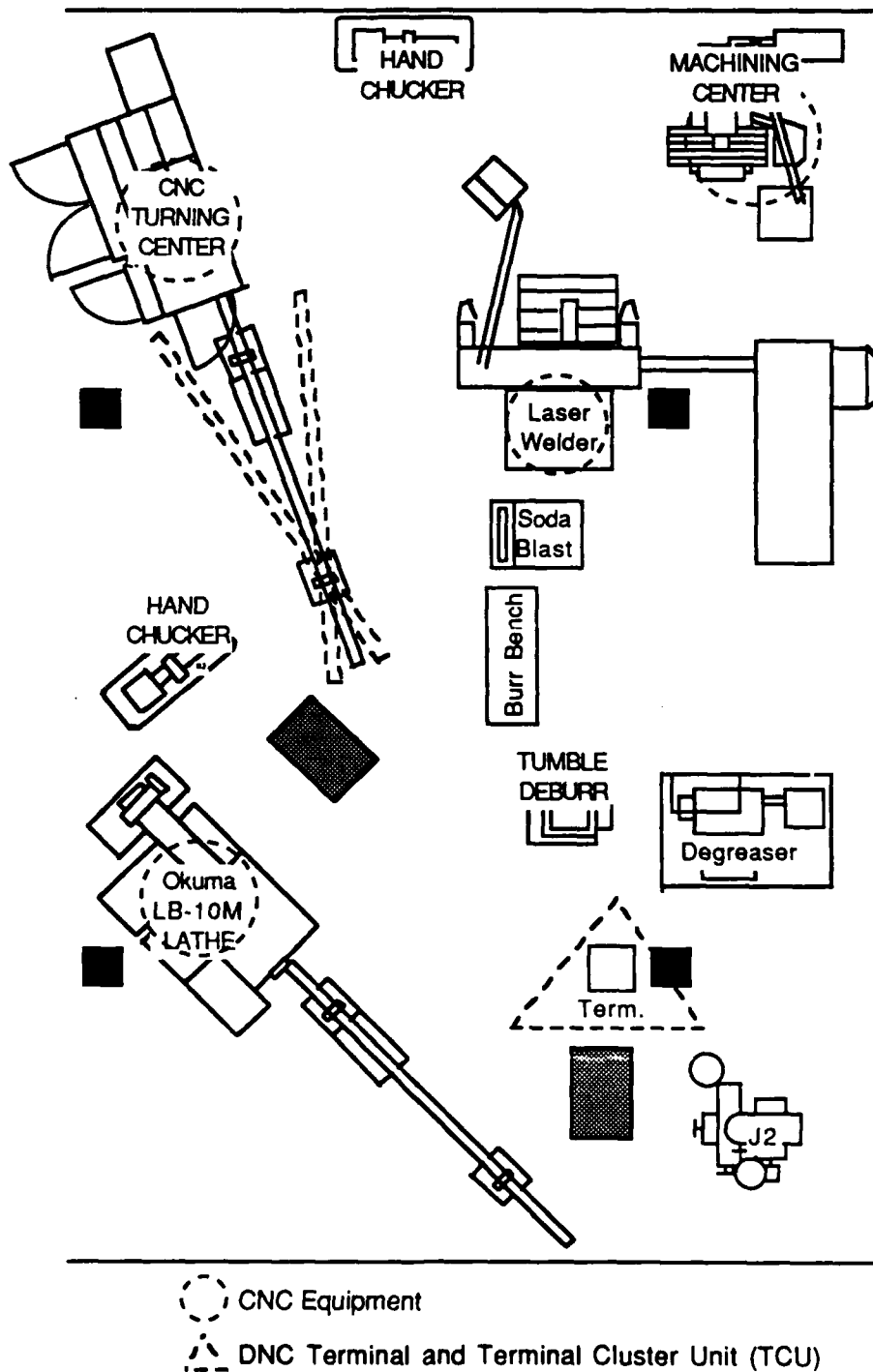


Figure 8.6 "To-Be" Walnut and Girth Ring Cell Terminal Location

# MODEL SHOP & SHORT RUN SHOP DNC TERMINAL LOCATION

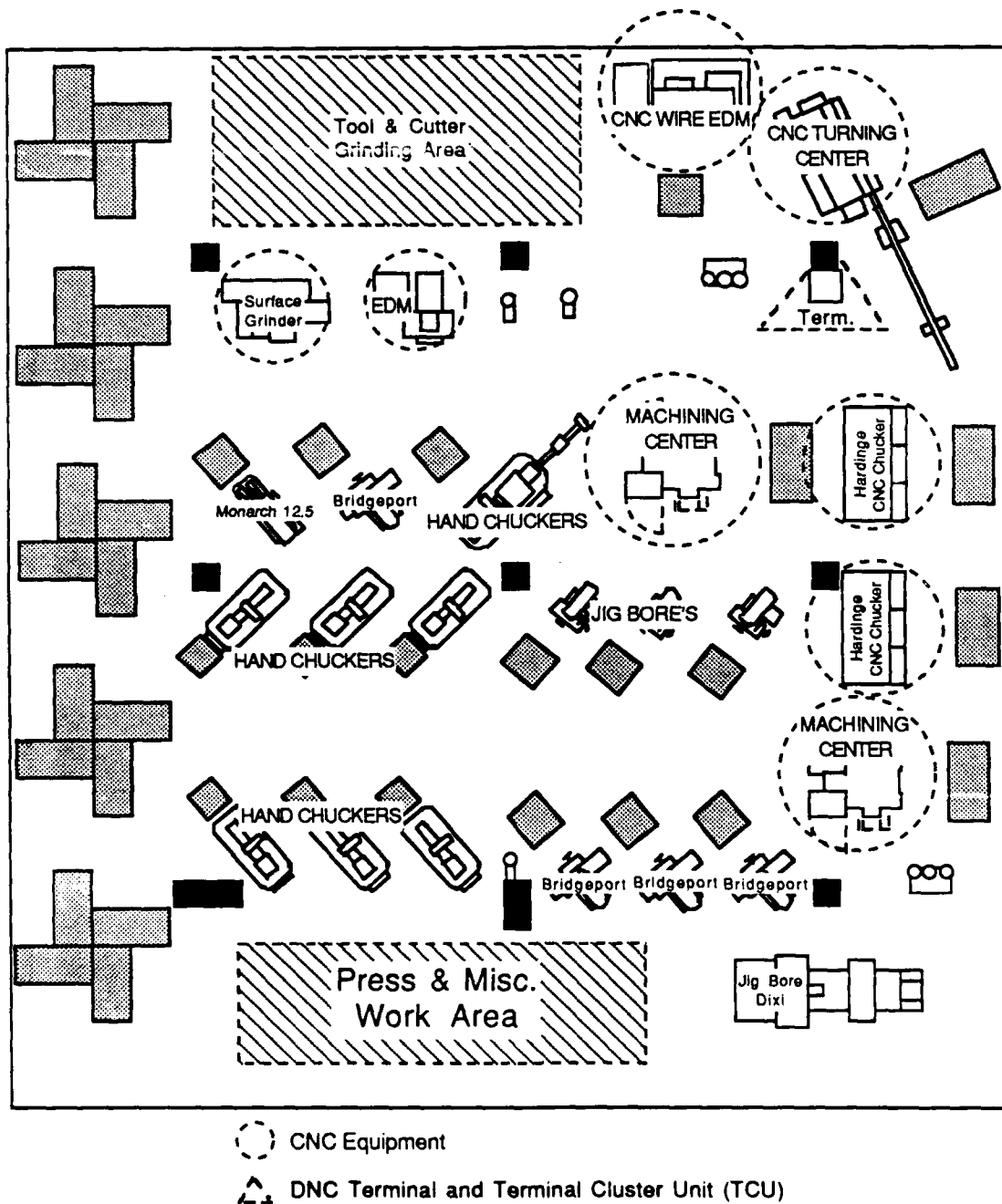


Figure 8.7 "To-Be" Model Shop and Short Run Shop DNC Terminal Location

# **SHEET METAL CELL DNC TERMINAL LOCATION**

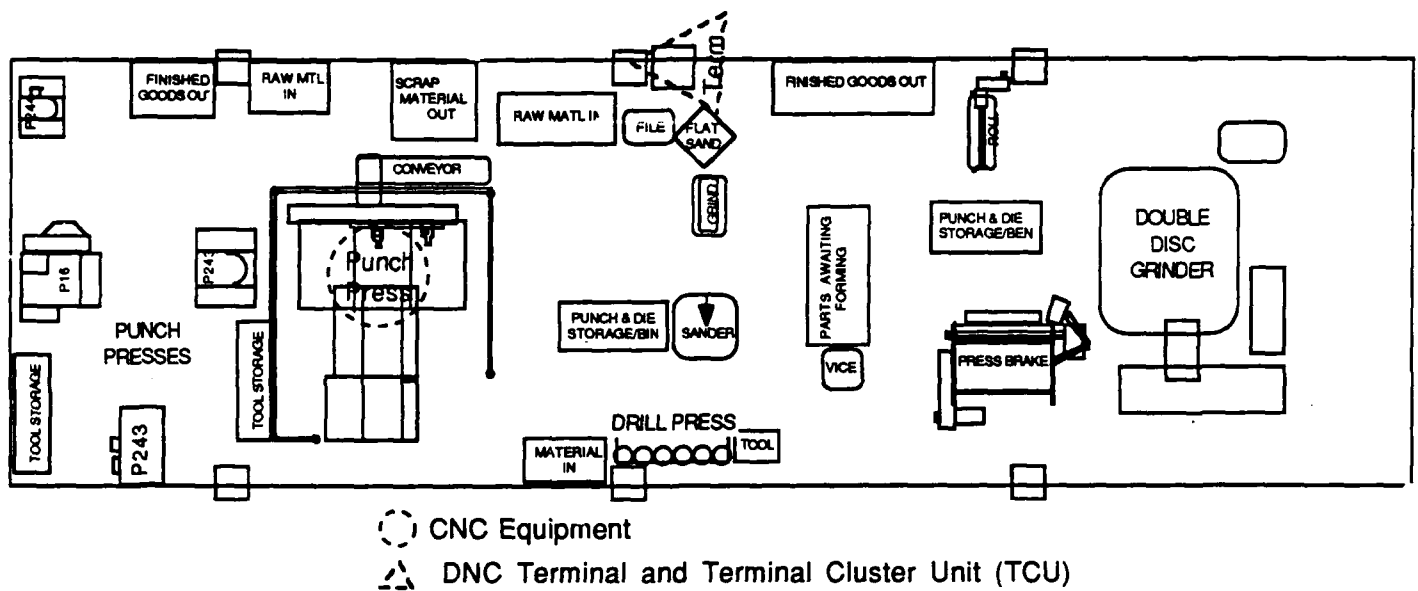


Figure 8.8 "To-Be" Sheetmetal Cell DNC Terminal Location

## DNC TERMINAL LOCATION



**Figure 8.9 "To-Be" Flex Shop DNC Terminal Location**

## SECTION 9

### SYSTEM/EQUIPMENT/MACHINE SPECIFICATIONS

The specifications required for the proposed Systems are:

#### NC PROGRAMMING

- Software
  - Interface with Computer Vision (CADD4X).
  - Three user capacity.
  - Ability to support 3 axis CNC machines.
  - Availability of post processors to support any CNC machine and control marketed in the U.S. today.
  - Machine control file editing (NC utilities).
  - BCL generating.
  - Interactive color graphics.
  - Sheetmetal unfolding capability.
- Hardware
  - Must support software as outlined.

#### DNC SYSTEM

- Software
  - Ability to support 41 CNC machines as configured in the final design of this segment.
  - Ability to interface with PC based CAD/CAM system.
  - Multi-user, multi-tasking capability.
  - BCL compatible.
- Hardware
  - Must support software as outlined.
  - File storage expandable.
  - User expandable.

## SECTION 10

### TOOLING SPECIFICATIONS

No tooling is required for the operation of the NC programming support system.



## SECTION 11

### VENDOR/INDUSTRY ANALYSIS/FINDINGS

An industry survey was conducted to identify NC programming system and DNC system suppliers as discussed in Section 3 of this document. The selection for potential suppliers was based on the following criteria (not listed by priority of importance):

- Product capability.
- Prior Honeywell vendor relationships.
- On-site visits.
- Price.
- Service and training support.
- Single supplier (same vendor supplies programming system and DNC system).

The three NC programming system suppliers selected to submit quotations were:

- Anderson O'Brien, Inc.  
St. Paul, Minnesota
- CIMCO  
Irving, Texas
- Computer Vision  
Bedford, Massachusetts

The four DNC system suppliers selected to submit quotations were:

- Anderson O'Brien, Inc.  
St. Paul, Minnesota
- CIMCO  
Irving, Texas
- Computer Vision  
Bedford, Massachusetts
- Crystal Corporation  
Minneapolis, Minnesota

Satisfactory responses were received from all suppliers with the exception of CIMCO. A satisfactory quotation was received from CIMCO for a NC programming system only. After contacting CIMCO several times by phone to request a DNC system quotation, no response was received.

After a through analysis of the various vendors, Anderson O'Brien Inc was the selected supplier. This was based on the fulfillment of the following criteria:

- Product Capability
  - As shown in Figures 11.1 and 11.2, Anderson O'Brien's product was superior or comparable to the other vendors system.
- Prior Honeywell Vendor Relationships
  - Honeywell has purchased hardware and software from Anderson O'Brien, Inc. in the past. The service received for hardware repair and technical support has been excellent.
- On-Site Visits
  - An on-site visit to Anderson O'Brien's was made. A live demonstration of the proposed NC programming system was given.
- Service and Training
  - Anderson O'Brien's personnel service their product and conduct the necessary operator training. Training classes are conducted locally. Classes are scheduled on an as-needed basis.
- Price
  - For comparable systems, Anderson O'Brien's system was less in cost.
- Single Supplier
  - Anderson O'Brien is a supplier of NC programming systems and DNC systems.

In response to the additional requirement to support a CNC punch press, it was found that Anderson O'Brien, Inc., markets a superior sheetmetal NC programming system.

Anderson O'Brien, Inc., is also able to supply the additional hardware and software needed to support the added DNC requirement discussed in Section 8 of this document. Quotations were requested and received for the DNC and CNC additional requirements.

## NC PROGRAMMING SYSTEM COMPARISON

SYSTEM REQUIREMENTS	VENDORS		
	ANDERSON OBRIEN INC.	COMPUTER VISION	CIMCO
IN-HOUSE SYSTEM	YES	YES	YES
NUMBER OF USERS	3 QUOTED	2 QUOTED	4 QUOTED
2 1/2 AXIS CAPABILITY MIN.	3 AXIS	2 1/2 AXIS	2 1/2 AXIS
INTERFACE WITH DESIGN'S CAD/CAM SYSTEM	YES (THROUGH IGES)	YES	YES (USE APT OUT FILE)
GENERALIZED POST PROCESSOR CAPABILITY	YES	YES	YES
SIMPLICITY OF INPUT	MENU OR LANGUAGE DRIVEN	MENU DRIVEN	LANGUAGE DRIVEN
BCL GENERATING	YES	YES	NO
INTERACTIVE GRAPHICS	YES	YES	YES
VENDOR TECHNICAL SUPPORT	LOCAL PHONE CALL OR VISIT TO VENDOR	LOCAL PHONE CALL	PHONE CALL'S TO DALLAS OR CHICAGO
MULTI-MACHINE SUPPORT - MILL/ LATHE/EDM/GRINDING	YES	YES	YES
AVAILABILITY OF TRAINING	LOCAL 4 DAY IN-HOUSE TRAINING AVAILABLE	2 WEEKS BEDFORD MASS.	1 WEEK LOCAL WITH NEW SYSTEM 1 WEEK LATER IN CHICAGO
AVAILABILITY OF MAINTENANCE CONTRACT	YES	YES	YES

Figure 11.1 NC Programming System Comparison

## DNC SYSTEM COMPARISON

	VENDORS		
SYSTEM REQUIREMENTS	ANDERSON OBRIEN INC.	COMPUTER VISION	XTAL CORP.
NUMBER OF USERS	30 QUOTED	24 QUOTED	30 QUOTED
EXPANDIBILITY	YES	YES	YES
STORAGE CAPACITY	340 MB	840 MB	80 MB
BCL COMPATIBLE	YES	YES	YES
AVAILABILITY OF TRAINING	3 DAYS IN-HOUSE	2 WEEKS BEDFORD MASS.	2 DAYS LOCAL
SHOP FLOOR EDITING	YES	YES	YES

Figure 11.2 DNC System Comparison

## SECTION 12

### EQUIPMENT/MACHINERY ALTERNATIVES

If the selected vendor's systems became unavailable, the following systems could be purchased:

#### NC PROGRAMMING SYSTEM

CIMCO would be the alternative NC programming system vendor. In comparison, the Computer Vision System quoted was more costly with less user capacity. However, this choice would mean the sacrifice of three important factors. They are as follows:

- BCL generating capability.
- CAD capability.
- Sheetmetal unfold capability.

The affect of eliminating these capabilities from the NC programming support system is:

- No benefit would result if BCL compatible CNC machines were purchased.
- Tool path would only be shown graphically in two dimensions.
- The creation of the flat format drawing would be accomplished manually.

#### DNC SYSTEM

Crystal Corporation markets a DNC system similar in specification to Anderson O'Brien's. However, the system is more costly.

## SECTION 13

### MIS REQUIREMENTS/IMPROVEMENTS

There are no current plans to network the NC programming support system with Honeywell Manufacturing System (HMS) or Process Management System (PMS). However, the system defined in this project segment will interface with design engineering's CADD system (Computervision, CADDs 4x). The reason for this interface is to capture three dimensional part data created on the CADD system during the drafting exercise.

Through the use of Initial Graphics Exchange Specifications(IGES), this data will be down-loaded to the sheetmetal CAD/CAM system or the machining CAD/CAM system. This geometry can then be used in the generation of flat sheet format drawings and the creation of machine control files minimizes re-definition. Since the CADDs 4x system is located in Honeywell's St. Louis Park facility, the communication medium for this interface will be a phone modem.

## SECTION 14

### COST BENEFIT ANALYSIS/PROCEDURE

#### OVERVIEW

The analysis of the NC Programming was broken down into two separate categories. This included machining computer aided design/computer aided manufacturing (CAD/CAM) and sheetmetal CAD/CAM systems. The separate analysis was due to the distinct differences in process flow paths between sheetmetal and machined piece parts requiring numeric controlled programming. Average hours per program were identified as the major cost driver. This identification used the methodology as illustrated in the process diagram on Figure 14.1.

#### MANUFACTURING SCHEDULE

New and revised tooling authorizations for NC programs were used as a basis for determining savings for the proposed machining system. Completed authorizations were obtained for 1986. Each MAVD's operations' revenue plan was obtained to perform a ratio analysis which developed a relationship between each revenue plan and the Fabrication Facility's programming activity. This ratio was calculated for a ten year period starting in 1988 and then applied to the quantity of tooling authorizations to determine the number of programs required for the same out year period.

The sheetmetal system savings were also based on the annual number of NC programs. To obtain a base year quantity, the monthly Production Engineering Work Log for 1985 was used. This report listed all new and revised production jobs that required processing or updating. From that list, the sheetmetal parts requiring NC programming were collected and totalled. The ten year volume projections were calculated using the same methodology as described in the previous paragraph.

#### ACTUAL STANDARD HOUR SAVINGS

An average hours per program was determined to be the basis for calculating savings. Each section of this programming cell used different means to obtain an average. The machining section used actual historical hours from 1984's Tooling authorizations and Sheetmetal hours were based on best engineering judgement, due to unavailable historical data.

The "To-Be" baseline was calculated by reducing the "As-Is" average hours by a factor of 40 percent. This conservative factor was determined by the Tech Mod team after receiving written recommendations from vendors who sell and support CAD/CAM programming systems. Their recommendations were based on systems already in place in other local companies which realized up to 75 percent reduction in processing time.

## COST BENEFIT ANALYSIS METHODOLOGY

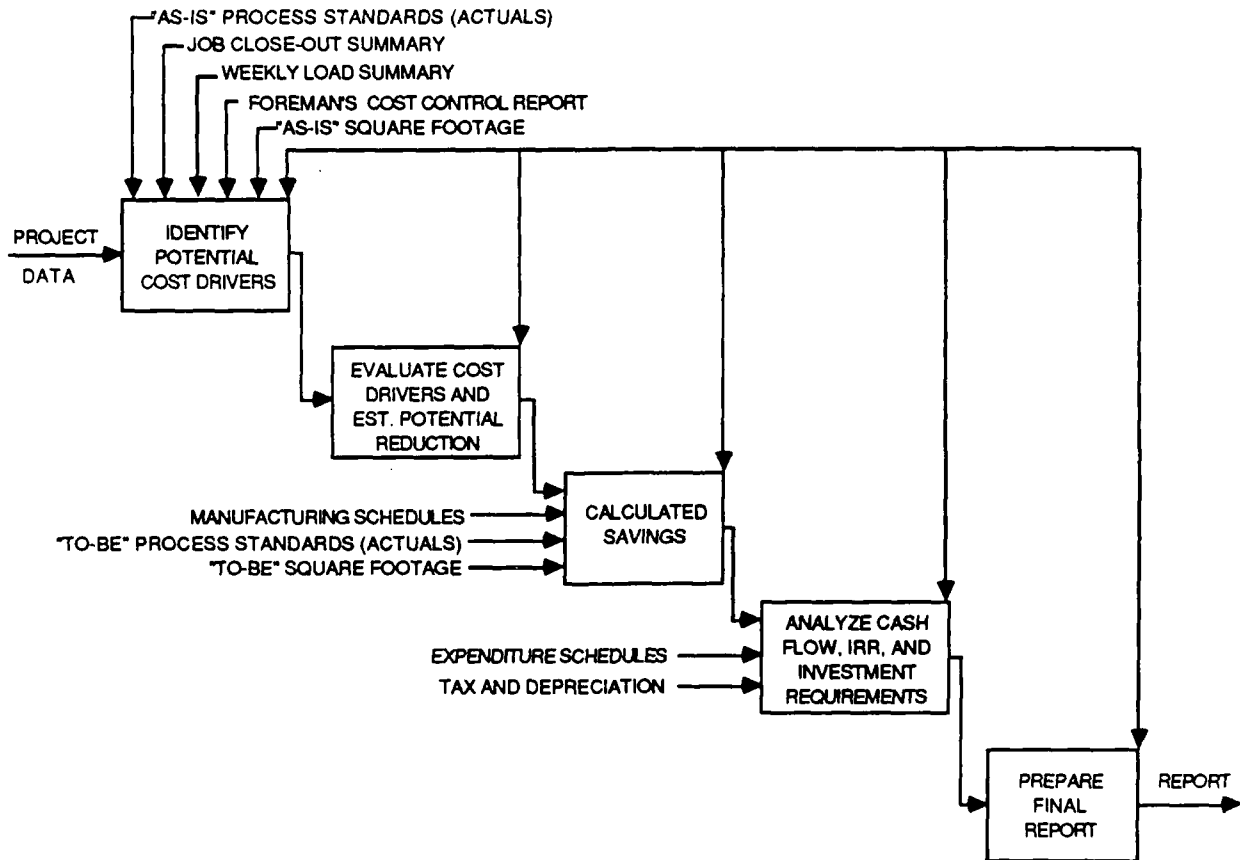


Figure 14.1 NC Programming Cost Benefit Analysis Methodology



In addition to the reduction in programming time, the elimination of a technician's support will be realized by the introduction of the Distributed Numeric Control (DNC) system. This system will eliminate the need to manually pull tapes for each order and hand deliver them to the production floor.

#### CAPITAL AND EXPENSE

The capital, recurring and non-recurring expense for the NC Programming are shown in Figure 14.2.

#### PROJECT SAVINGS AND CASH FLOWS

The savings to be realized by this cell exceeds Honeywell's Military Avionics Division hurdle. The cell's cash flows are shown in Figure 14.3 with the assumption that capital is available per the implementation plan.

**NUMERIC CONTROL PROGRAMMING CELL  
EXPENDITURE SCHEDULE**

		Capitalization	Year	
		Date	Cost	Expended
CAPITAL COSTS				
COMPUTER COSTS				
Machining CAD/CAM System	1987	\$84,007		1988
Sheet Metal CAD/CAM System	1987	\$43,559		1987
.. DNC Computer Hardware	1988	\$118,679		1988
.. DNC Link (Material)	1988	\$1,608		1988
.. DNC Link (Material)	1989	\$3,215		1989
.. DNC Link (Material)	1990	\$1,608		1990
	1987	\$127,566		1987
	1988	\$120,287		1988
	1989	\$3,215		1989
	1990	\$1,608		1990
		-----		
TOTAL COMPUTER COSTS		\$252,676		
FURNITURE COSTS				
.. Work Station Furniture	1988	\$2,351		
.. Work Station Furniture	1989	\$1,822		
.. Work Station Furniture	1990	\$1,367		
		-----		
TOTAL FURNITURE COSTS		\$5,540		
	1987	\$127,566		
	1988	\$122,638		
	1989	\$5,037		
	1990	\$2,974		
		-----		
TOTAL CAPITAL COSTS		\$258,216		
EXPENSE COSTS				
NON-RECURRING EXPENSES				
Area Preparation Labor (HI)			\$10,440	1988
Training (HI)			\$2,500	1987
Hardware Installation Labor			\$5,400	1988
Hardware Installation Labor			\$10,800	1989
Hardware Installation Labor			\$8,220	1990
			-----	
			\$2,500	1987
			\$15,840	1988
			\$10,800	1989
			\$8,220	1990
			-----	
TOTAL NON-RECURRING COSTS			\$37,360	
			-----	
TOTAL CAPITAL + NON-RECURRING			\$295,576	
RECURRING EXPENSES				
.. Annual Maintenance (Computer HW)			\$2,913	
.. Annual Maintenance (Computer SW)			\$2,796	
			-----	
TOTAL RECURRING			\$5,709	
.. Expense starts in year 2.				
.. Costs contain a 15% contingency				

Figure 14.2 NC Programming Expenditure Schedule

TECH MOD PHASE 2  
PROJECT 44 - NC PROGRAMMING CELL  
PROJECT CASH FLOW SUMMARY  
(\$000)

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	TOTAL
Capital	\$127.6	\$122.6	\$5.0	\$3.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$258.2
Non-Recurring Expenses	\$2.5	\$15.8	\$10.8	\$8.2	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$0.0	\$37.4
Recurring Expenses	\$2.9	\$5.6	\$5.7	\$5.7	\$5.7	\$5.7	\$5.7	\$5.7	\$5.7	\$5.7	\$5.7	\$5.7	\$65.5
Total Savings	\$0.0	\$62.8	\$99.3	\$138.9	\$193.1	\$219.0	\$247.6	\$278.1	\$308.7	\$334.9	\$364.6	\$82.7	\$2,329.8
Depreciation	\$12.8	\$37.6	\$50.2	\$50.8	\$51.0	\$38.2	\$13.5	\$1.1	\$0.6	\$0.5	\$0.5	\$1.5	\$258.2

Figure 14.3 NC Programming Cash Flows

## SECTION 15

### IMPLEMENTATION PLAN

The implementation plan for the NC programming support system is divided into three individual categories:

- Machining CAD/CAM system.
- Sheetmetal CAD/CAM system.
- DNC system.

The implementation plans for the machining CAD/CAM system and sheetmetal CAD/CAM system are unique. The machining CAD/CAM system was purchased in July, 1987 and is scheduled for installation in late August. A Capital Appropriation request has been submitted for the sheetmetal CAD/CAM system with plans to issue a purchase order in the fourth quarter of 1987.

The following is a description of the activities shown on the NC programming support system implementation plan schedule (reference Figure 15.1).

#### MACHINING CAD/CAM SYSTEM

A purchase order was issued and the system has been received. It will be installed in the current NC programming area. Relocation will occur in the third quarter of 1988 in conjunction with the completion of the office layout change.

Vendor supplied training for the CNC programmers will occur simultaneously with an ongoing on-the-job training effort.

The time-sharing service currently in use will be discontinued when familiarization with using the CAD/CAM system has been achieved.

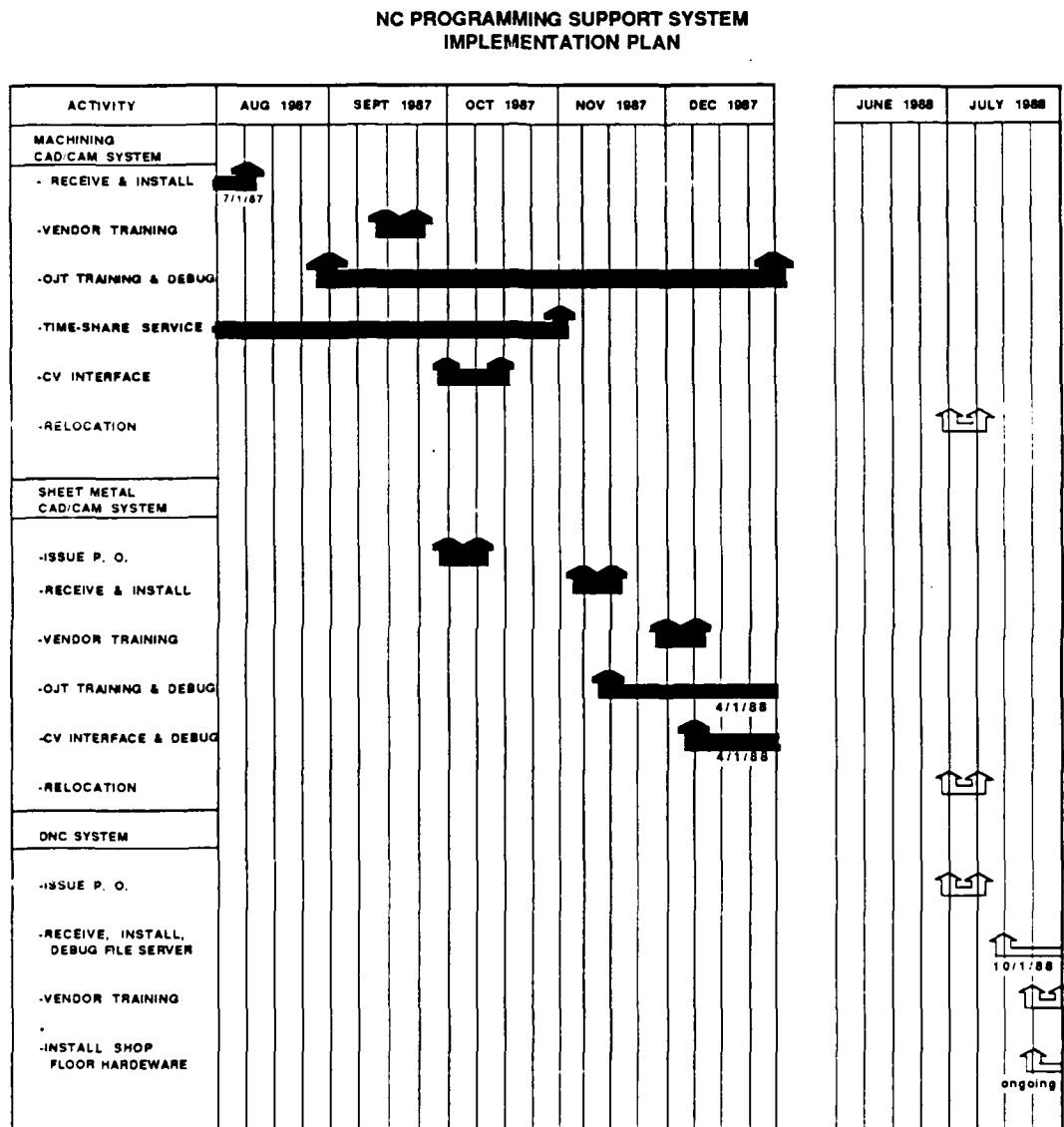
#### SHEETMETAL CAD/CAM SYSTEM

After installation is complete, vendor supplied training will occur simultaneously with an ongoing, on the job training effort. Relocation of this system will occur in the third quarter of 1988 with the completion of the office layout change (reference segment one of project 44).

#### DNC SYSTEM

With the installation of the file server the integration of the CAD/CAM systems and the DNC system will be completed. The installation of the Terminal Cluster Units (TCUs) and shop floor terminals will be dependent upon the individual machining cell or shop area implementation plan.

Training for the NC programmers will be conducted by the vendor in-house after installation of the file server is complete. Operator training for the shop floor terminals will be on-going with the implementation of the individual machining cells or shop area.



\* Installation of shop terminals and operator training are dependent on the implementation schedule of each machining cell or shop area.

Figure 15.1 NC Programming Support System Implementation Plan

## SECTION 16

### PROBLEMS ENCOUNTERED AND HOW RESOLVED

#### ADDITIONAL REQUIREMENTS FOR SHEETMETAL SUPPORT

The Phase 1 report assumed the elimination of the punch press area. However, changes in the current and projected sheetmetal loads from Honeywell's Test Systems and Logistics Operations caused a reversal of this plan. A considerable portion of this project segment had to be re-evaluated when this requirement was added.

#### RESOLUTION

A study was made of sheetmetal programming systems that would interface with design engineering's CADD system and meet the requirements established by the Sheetmetal Cell. One system was found with software capable of generating a flat format drawing from three dimensional data. A quotation was requested and received.

## SECTION 17

### AREAS FOR FUTURE CONCERNS/DEVELOPMENT

#### FUTURE CONCERNS

System networking becomes a concern with the lack of an accepted industry standard. The NC Programming Support System proposed in this segment will interface with Design Engineering's CADD system through IGES. If the parameters of Design Engineering's CADD system change, this interface may be affected.

#### FUTURE DEVELOPMENT

- **NC Programming System**  
As the Binary Cutter Location Exchange Format (BCL) is more accepted as an industry standard, BCL based machine tools will become increasingly available. The NC programming systems proposed in this project segment are BCL generating. Therefore, if BCL compatible machine tools are utilized in Fab Fac's future, the use of post processors and their creation could be eliminated.
- **DNC System**  
As Fab Fac moves toward implementation of CIM, the utilization of the DNC system could be expanded. In addition to down-loading machine control files, DNC may electronically transfer manufacturing process data typically sent to the shop in a "Traveler". The DNC system, due to its bi-directional capabilities may also be used as a monitoring device. Automated discrete signal acquisition within a DNC network can tap into such parameters as feed and speed overrides, power on, auto mode, and feed hold. This monitoring can provide the type of feedback that is required to optimize manufacturing operations.

## PROJECT 44

### T-BAR CELL

#### SECTION 1

#### INTRODUCTION

The T-Bar (Torsion Bar) is a critical component part in the GG4400 and GNAT gyros. There are several configurations of Torsion Bars to meet specific gyroscope requirements. Cell layout for part storage or transport are simplified by part size. A typical order of 4000 parts will not fill a 2 cup container. They all share a basic center necked hourglass shape. They range in approximate lengths from .3 inches to .7 inches. Diameters, of opposing ends, range from approximately .070 inches to .25 inches. The necked center section range is from .016 inches to .030 inches. Typical surface finishes range from 8 to 20 rms. Burrs or stress marks caused by deburring, machining or grinding which are detectable under 10 power magnification, are cause for rejection. Some of the larger torsion bars have cylindrical threaded patterns on ends *for mechanical fostering* to gyroscope components. Tolerances for size, runout, perpendicularity and concentricities use  $\pm .0002$  inches total for most configurations. T-Bars are completely manufactured in the Fabrication Facility, and are delivered to the Precision Control Instruments (PCI) department for assembly in gyroscopes.

The "T-Bar Cell" will reduce lead time, Work-In-Process (WIP) inventory, and will improve material handling and control. Details of the machining cell manufacturing approach and its formation will follow.

The T-Bar Cell will not be implemented. A change in foreign exchange rates (which increase the equipment cost) and a reduction in marketing forecast resulted in an unacceptable internal rate of return and equipment utilization. The project will be reevaluated if these economic conditions change significantly. This partial disclosure will be included in the Project 44 final report to document the effort expended and to aid in reopening the project at a possible future date.



## SECTION 2

### PROJECT PURPOSE/OVERVIEW

The purpose of this project was to determine the feasibility of replacing two government manual grinding machines with a CNC (Computer Numerical Control) crush form grinder, and the feasibility of updating the manual turning machines with a 1/2" bar CNC machine.

The objectives were to maximize the utilization and payback on these machines and to ultimately improve throughput time with reduced part cost.

The first approach to accomplish the objectives was to compare current purchase price to cost of manufacturing the parts in-house on the new CNC crush form grinder and 1/2" bar CNC machine. The second approach was to compare current production process hours (Standard time) on the manual machines to 1/2" bar CNC machine.

If it is found that the estimated cost of manufacturing the parts in-house on the new machines is less than the current purchase price, purchase of those machines will be considered. Production process hours are also expected to be less on the new machines, which should improve throughput time and reduce cost.

## SECTION 3

### TECHNICAL APPROACH

An engineering team was formed to evaluate work cell potential for the T-Bar family of parts. The investigative base was the parts list and preliminary design concepts developed by the Project 44 core team. The technical approach to the evaluation/ investigation was as follows:

1. Structured matrix to show total hours spent on each machine for all parts currently being manufactured in the current manual grinders and supporting lathes. The potential for improvement, actual labor costs and a rough preliminary design was supplied by the project core team, as described in Section 3 of the Project Overview.
2. Selected replacement machines according to their ability to meet the objectives of maximum utilization, process consistency, rate of return, and improved throughput time.
3. Developed work cell layout, labor costs and cell load equipment utilization to determine percentage of load on each machine.
4. Calculated internal rate of return on the capital investment required by departmental and divisional approved methodology. The price of grinders had risen dramatically from previous bids due, in part, to currency exchange rate revisions.
5. Concluded the study since it did not meet project guidelines. All lathe produced parts were merged with the 1 1/2" Bar Cell project. Subcontract grinding vendors, with equipment specified in the proposed "To-Be" design were contacted to bid the grinding operations. This resulted in competitive bids which are being evaluated for an out sourcing decision on the grinding operations.
6. Completed applicable sections of the final report structure to document effort expended and to document the project for restudy if economic or volume factors change significantly.

## SECTION 4

### "AS-IS" PROCESS

The "As-Is" conditions for the Fabrication Facility (Fac Fab) area in general are detailed in Section 4 of the Project Overview. This section details only those items that are unique or specific for the parts groups mentioned below.

T-Bars are miniature parts that mechanically transmit detected motion to electronic output coils in the gyroscopes. There are two basic types of torsion bars used on the GG4400 and GNAT family gyroscopes. The part used on the GNAT gyroscope group is of beryllium copper (Reference Figure 4.1) while the GG4400 gyroscope family uses a less complex design made of stainless steel.

#### BERYLLIUM COPPER T-BAR

The GNAT torsion bar follows a complex path during the manufacturing. The maze of operations (Figures 4.1) includes turning, grinding, drilling, tapping, lapping, heat treating, chemical cleaning, calibration, and five bench operations that rely on well trained operators with excellent manual dexterity. Since operators do not have direct contact with each other, they are not always aware of the interaction or consequences of their efforts on downstream operation yields. The eighteen moves (Figure 4.2) the product makes during the manufacturing process increases lead times, makes parts physically difficult to locate, schedule, and reduce Work-In-Process inventories.

The final grind dimension, on the part neck, must meet both a final size and K factor range. The part is tensioned, by a test fixture, along it's radial axis and the released. The spring back distance/rate is calculated by an electro-mechanical test fixture electronically connected to the test fixture to determine the K factor.

#### STAINLESS STEEL T-BAR

The process flow of the GG4400 torsion bar is quite simple (Figure 4.3). The basic material is a procured blank of hardened and ground stainless steel. Two styles, one with the other without a chamfer, are used. The blanks are laser scribed for identification in the Precision Control Instruments (PCI) laser welder and moved to the Fab Grinding area (Figure 4.4). The grinding process uses either of two government owned manual machines, modified with synchronous drivers, to machine the approximate .100 inch diameter down to a neck of .016 inch. The border of the larger diameter with the small diameter must be manually deburred with a die file and jewelers lathe. If the .016 inch diameter is nicked, it often produces a stress line that is not detectable at 10 power magnification. This stress line has been attributed to fracture of torsion bars, and gyroscope failure in the PCI assembly area. The effects on shipped units are not known.

**T-BAR CELL  
AS IS PROCESS FLOW DIAGRAM**

**BERYLLIUM COPPER T-BAR  
GNAT GYRO ONLY**

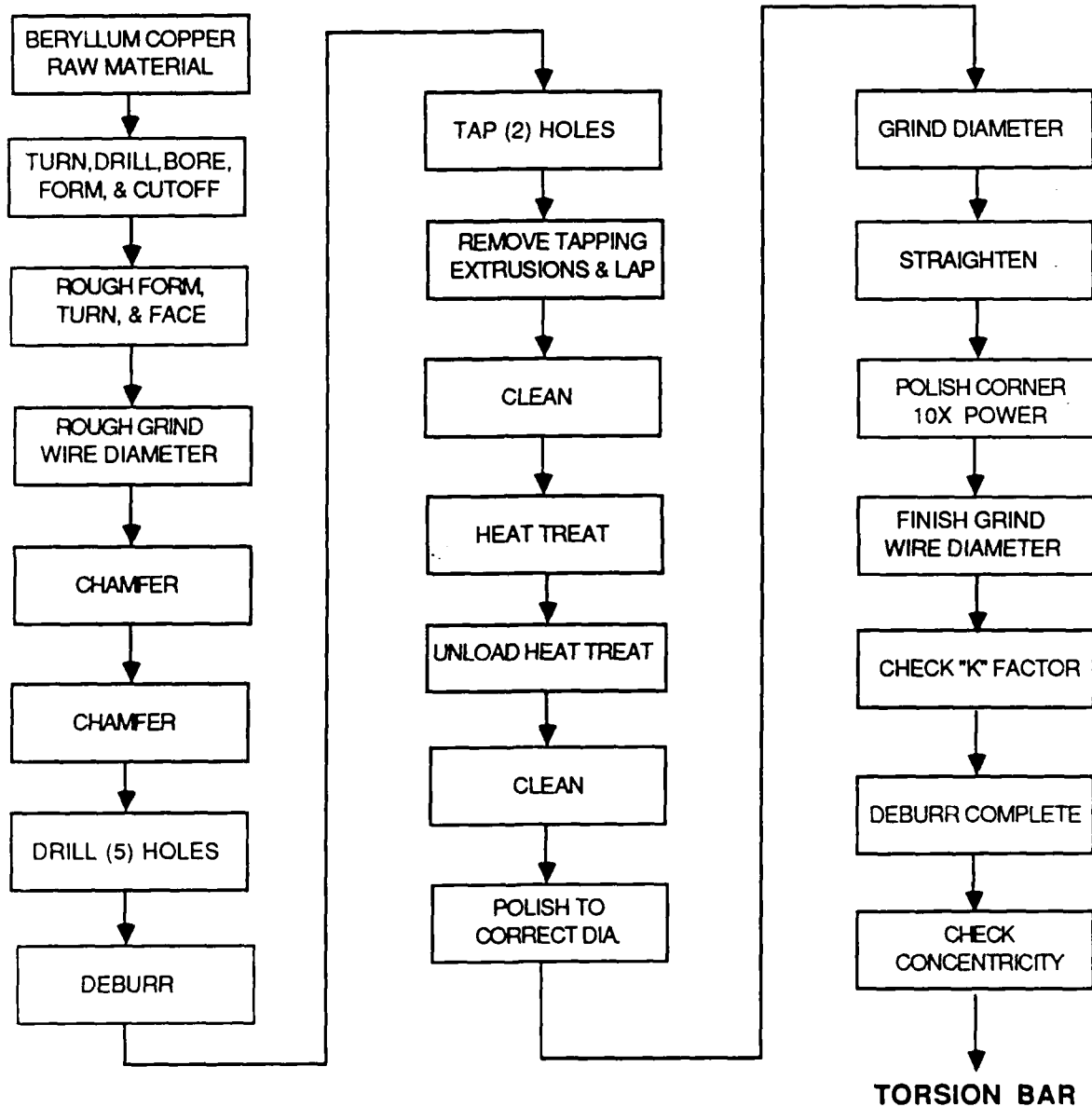
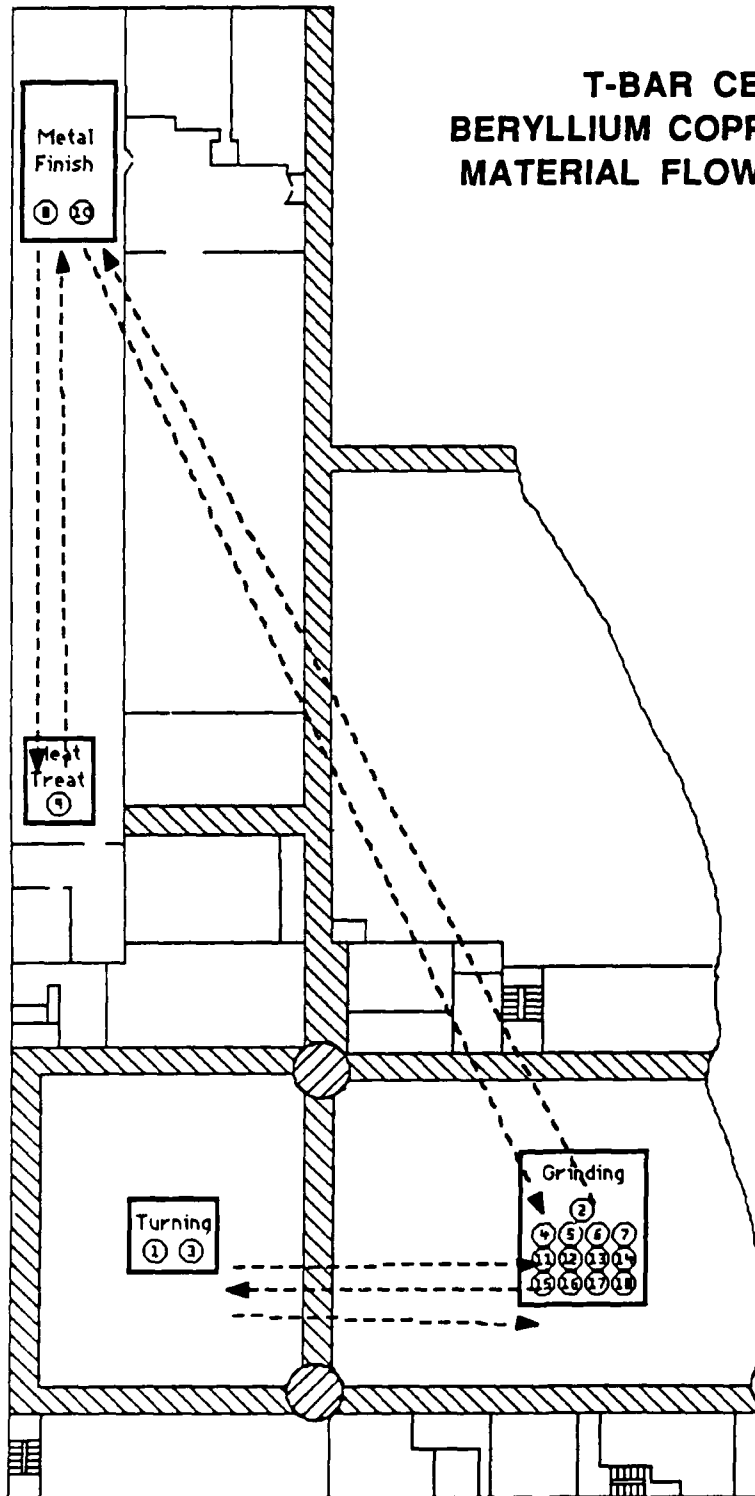


Figure 4.1 "As-Is" Beryllium Copper T-Bar Process Flow

**T-BAR CELL  
BERYLLIUM COPPER T-BAR  
MATERIAL FLOW -- AS IS**



1. Turning Mach. (2)
2. Grinding Mach.
3. Turning Mach.
4. Drilling Mach.
5. De-Burr
6. Tapping Mach.
7. Lap Mach.
8. Clean
9. Heat Treat
10. Clean
11. Polishing
12. Grinding Mach.
13. Straighten
14. Polish
15. Grinding Mach.
16. Check "K" Factor
17. De-Burr
18. Check Concentricity

Figure 4.2 "As-Is" Beryllium Copper T-Bar Material Flow

**T-BAR CELL  
AS IS PROCESS FLOW DIAGRAM**

**STAINLESS STEEL T-BAR  
GG4400 GYRO ONLY**

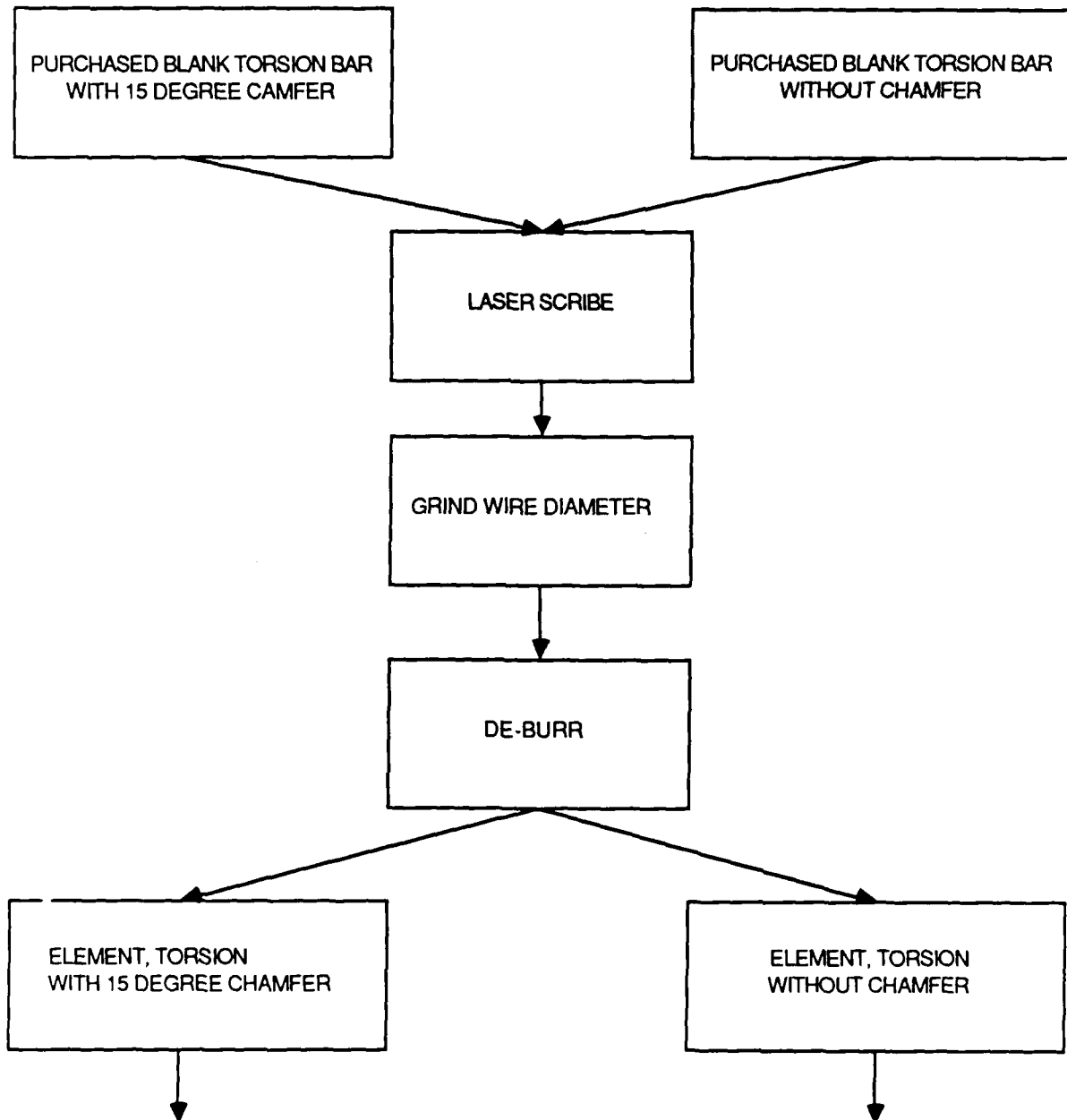
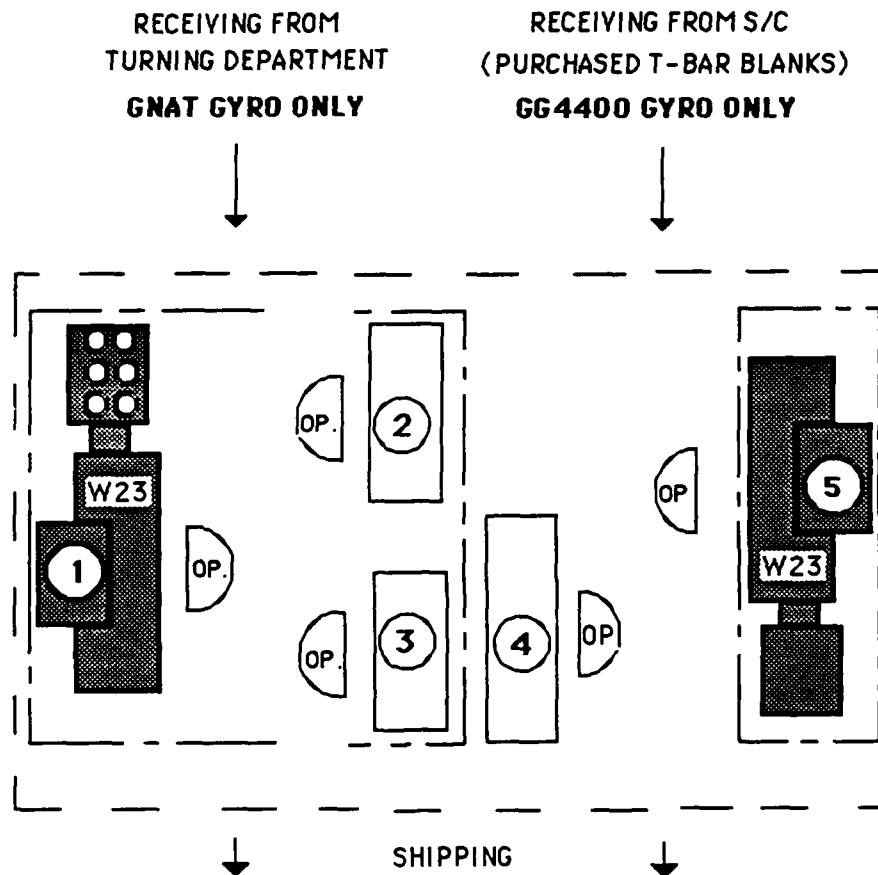


Figure 4.3 "As-Is" Stainless Steel T-Bar Process Flow

# T-BAR CELL

AS IS



- ① GRIND WIRE DIAMETER
- ② DE-BURRING
- ③ CHECK "K" FACTOR
- \* ④ DE-BURRING
- \* ⑤ GRIND WIRE DIAMETER

\* GG4400 ONLY

Figure 4.4 "As-Is" T-Bar Layout

## SECTION 5

### "TO-BE" PROCESS

The "To-Be" conditions for the Fabrication Facility (Fab Fac) area in general are detailed in Section 5 of the Project Overview. This section details only those items that are unique or specific for the parts groups mentioned below.

The manufacturing process for the beryllium copper T-Bar (Reference Figure 5.1A) has been reduced in numbers of operations and labor hours to produce. The Stainless steel T-Bar (Reference Figure 5.1B) is ground by a crush grind machine that leaves no burrs and eliminates potential part failure due to stress cracks created by deburring files. Both products are co-located in a single manufacturing work cell. There is minimum changeover requirements as each part is scheduled by Honeywell's MRP system (HMS). The Capacity Requirements Planning module is used to schedule and load level the cell to reduce changeover costs and to fully utilize the capital equipment. A working description of the cell components in each mode of operation is discussed below.

#### BERYLLIUM COPPER T-BAR

The process has been simplified and substantially reduced in labor content, lead time, Work-In-Process, and knowledge of complete process requirement by all operators that manufacture the part (see Figures 5.1 and 5.2).

The CNC lathe used is the latest technology available. It has a Swiss style headstock and bushing for front turning, a rear mounted chuck with a synchronous spindle capable of transferring a cut off part and ejecting a finished part, and a turrets capable of using tools on either the bar or chuck end. The turret has powered tools to do drilling and tapping operations on the chuck held parts. One drilling operation and removal of all burrs created by the turning machine are completed by the lathe operator as chores, internal to the lathe machine cycle.

The joint effort of grinding the wire diameter, checking and recording the K factor are as described in the "As-Is". The added chore of removal of the grind burr, internal to the testing cycle, has been added to the grinder operators duties.



**T-BAR CELL  
TO BE PROCESS FLOW DIAGRAM**

**BERYLLIUM COPPER T-BAR  
GNAT GYRO ONLY**

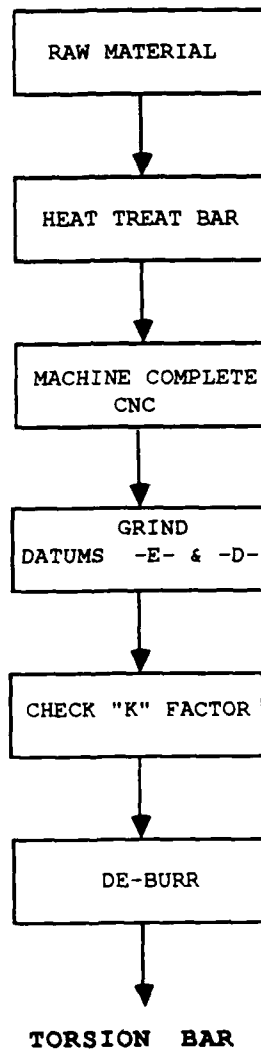
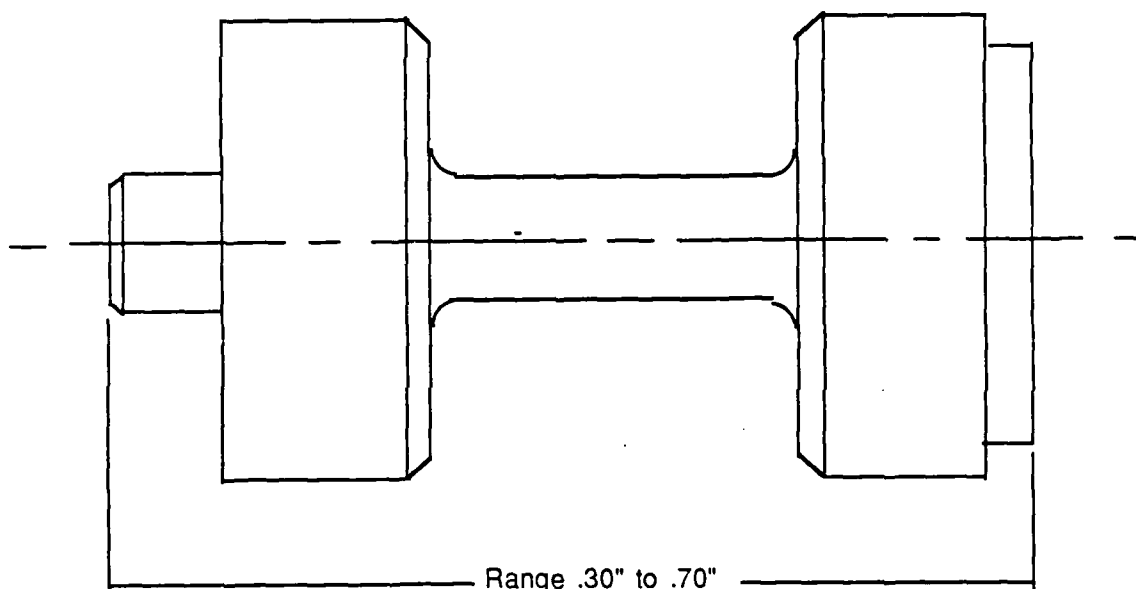


Figure 5.1 "To-Be" Beryllium Copper T-Bar Process Flow



End Diameter range from .070" to .25"

Center Diameter range from .016" to .030 "

Figure 5.1A Beryllium Copper T-Bar Illustration

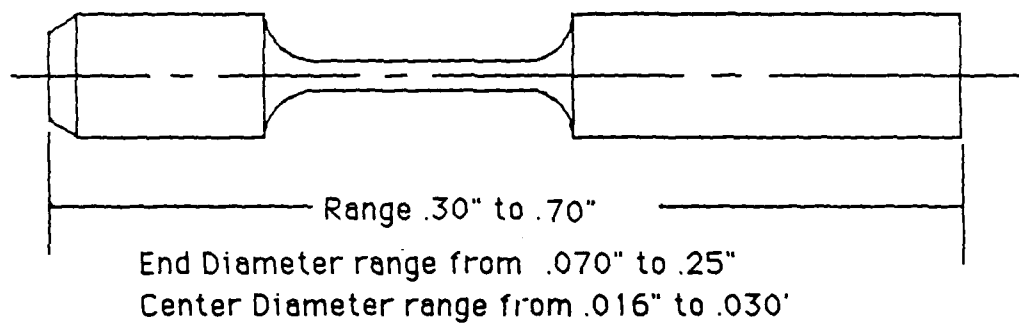
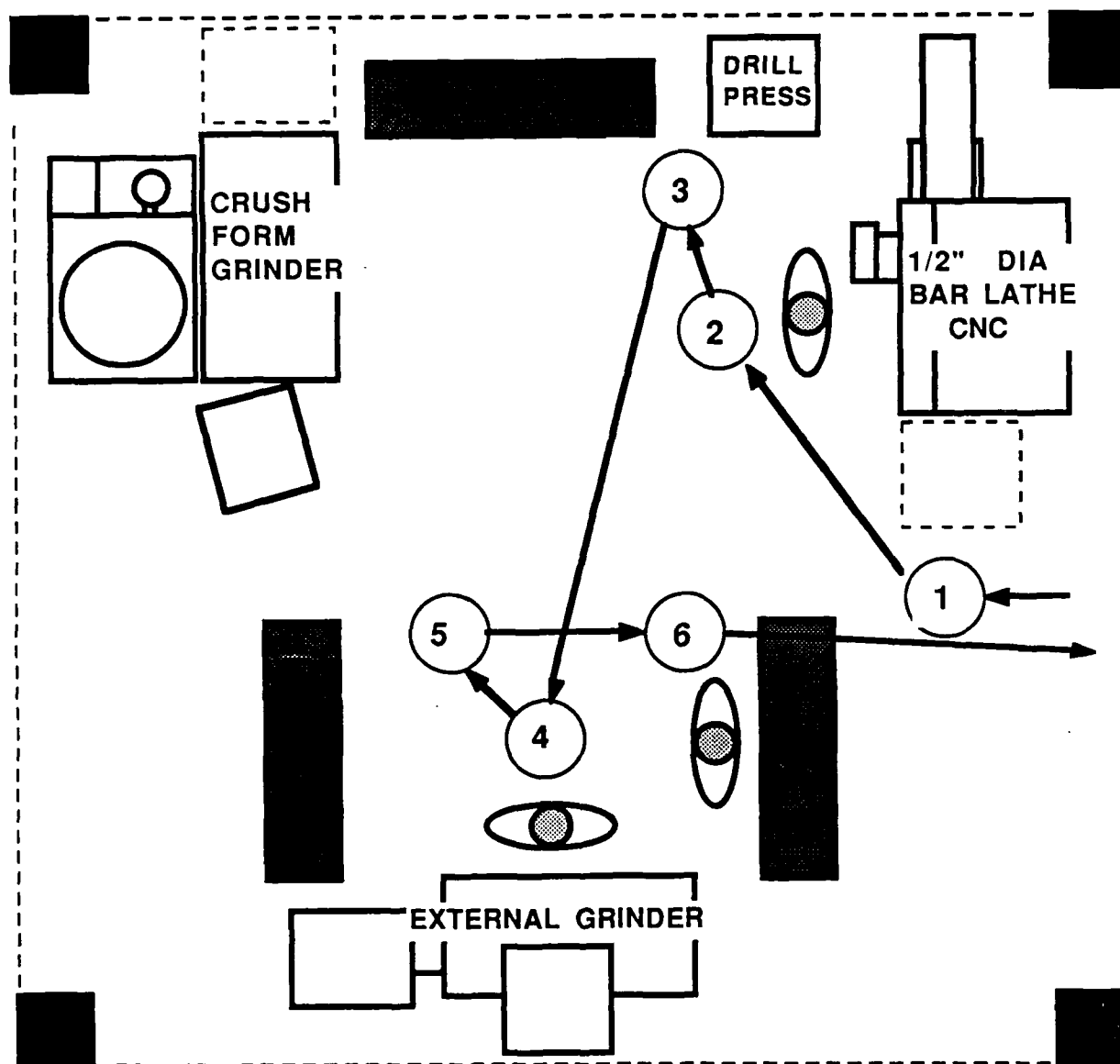


Figure 5.1B Stainless Steel T-Bar Illustration

# T-BAR CELL LAYOUT AND MATERIAL FLOW TO BE GNAT ONLY -- PHASE 2



- |  |                     |
|--|---------------------|
| 1. HEAT TREAT (BAR)                      | 4. GRIND WIRE DIA.  |
| 2. MACHINE COMPLETE                      | 5. DE-BURR          |
| 3. DRILL .025 DIA. (SECONDARY OPERATION) | 6. CHECK "K" FACTOR |

Figure 5.2 "To-Be" Beryllium Copper T-Bar Cell Layout

## STAINLESS STEEL T-BARS

Stainless steel bars are delivered to the work cell from stores. Batch processing is used to produce turned, unground blanks (see Figures 5.3 and 5.4). The blanks are chamfered or not chamfered per order requirements. The blanks are heat treated in Fab and laser scribed in either the PCI's laser welder or Fab's Girth Ring Cell laser welder as scheduled by the CRP module of HMS.

The blanks are crush ground to both the large diameter, wire diameter and neck radius simultaneously. The process does not leave a burr or create potential stress fault lines that could result in assembly or field failures.

## CNC LATHE - 1/2" DIAMETER

Excess capacity on the 1/2" diameter lathe is shared with the Flexible Machining Area. It acts as a buffer to workloads on the 1 1/2" Bar process line. Operators for the lathe are shared with the Flex Shop area.

To manufacture the beryllium copper T-Bar for the GNAT gyro, the 1/2" bar machine, grinding machine, and drill press are used.

The following sequence takes place when a GG4400 T-Bar is processed in this cell:

- Heat treat 1/4" diameter bar.
- Machine part complete (Front and Back).
- The first part is checked and verified by inspector.
- Drill one hole offset center of part on cutoff end on drill press as a chore.
- Grind outside diameter groove.
- Deburr part complete.
- Check the K factor.

## MANPOWER REQUIREMENTS

Operator #1 sets up the 1/2" bar machine. Parts come to the bar machine with heat treat complete. Then parts are run and chores are performed on drill press. Inspector checks parts for verified conformance to print.

Operator #2 sets up the grinding machine and grinds wire diameter. During the machine cycle time, operator deburrs complete parts. First part is checked and verified by inspector.

Operator #3 checks the K factor for verified conformance to print.

**T-BAR CELL  
TO BE PROCESS FLOW DIAGRAM**

**STAINLESS STEEL T-BAR  
GG4400 GYRO ONLY**

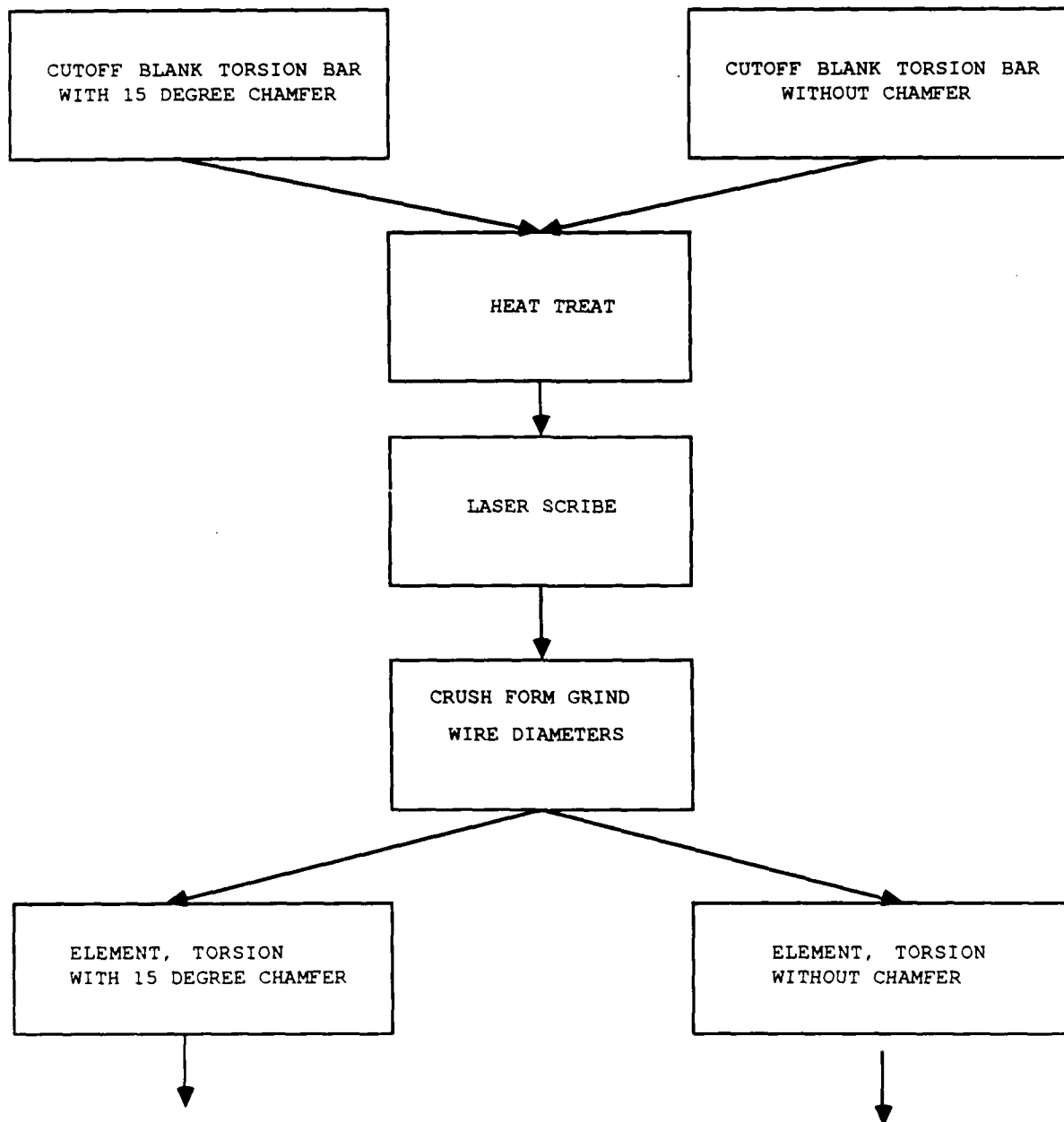
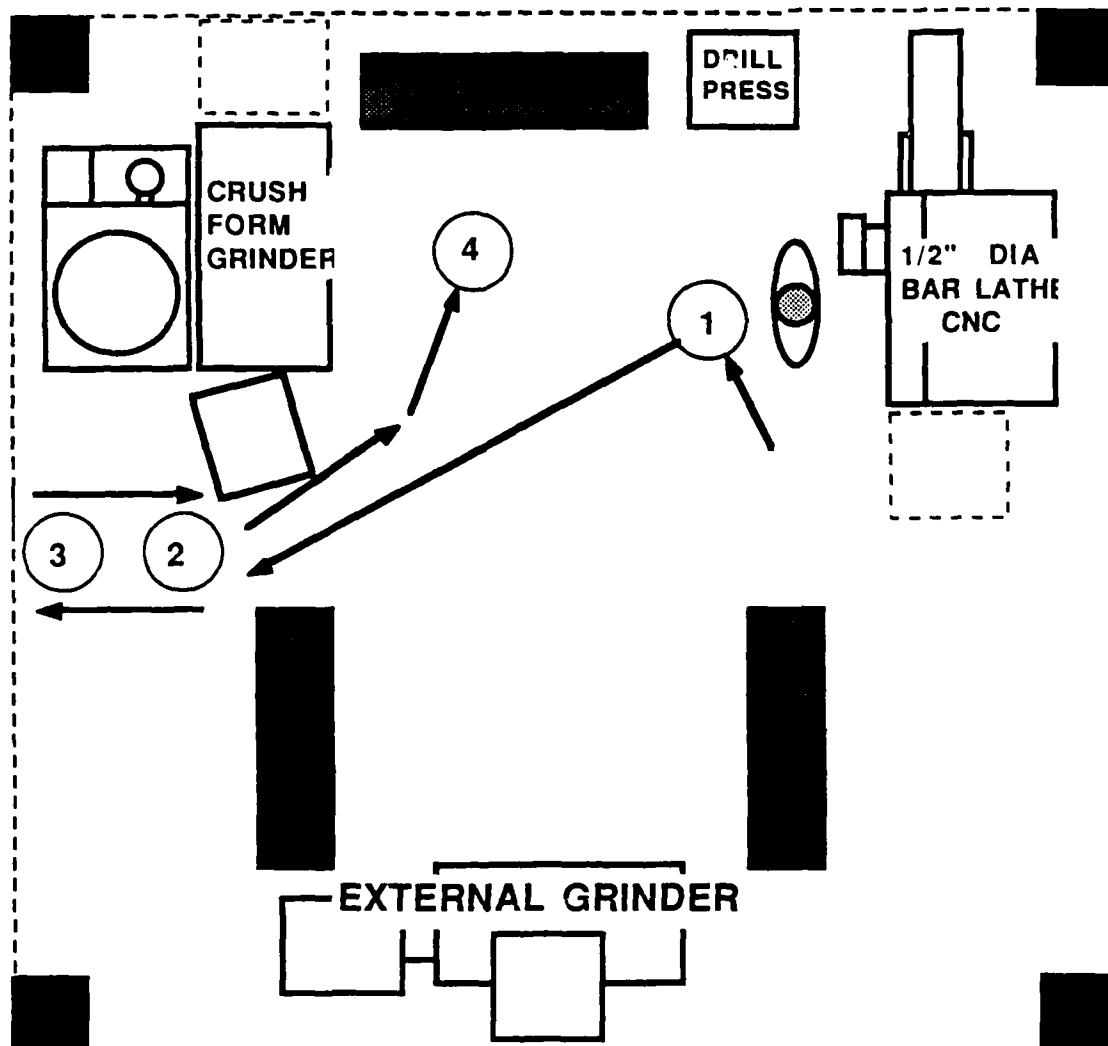


Figure 5.3 "To-Be" Stainless Steel T-Bar Process Flow

**T-BAR CELL LAYOUT AND MATERIAL FLOW  
TO BE  
GG4400 ONLY -- PHASE 2**



1. CUTOFF T-BAR BLANKS
2. HEAT TREAT
3. LASER SCRIBE
4. CRUSH FORM GRIND

Figure 5.4 "To-Be" Stainless Steel T-Bar Layout

## SECTION 6

### PROJECT ASSUMPTIONS

This project will not be implemented due to unfavorable changes in foreign exchange rates (which increase the equipment costs) and a reduction in market forecast. If these factors change enough to meet internal hurdle rates for machine utilization and internal rate of return, the project will be scheduled for implementation.



## SECTION 7

### GROUP TECHNOLOGY CODING SYSTEM ANALYSIS

Due to the small base of parts applicable to the T-Bar Cell, no group technology coding system/analysis was applied other than described in Section 7 of the Project Overview.

## SECTION 8

### PRELIMINARY/FINAL DESIGN AND FINDINGS

An engineering team was formed to evaluate the work cell potential for the T-Bar family of parts. The investigative base was the parts list and preliminary design concepts developed by the Project 44 core team. The discussion below describes all project findings and the evolution from preliminary to final design and project suspension.

#### PRELIMINARY DESIGN

The preliminary T-Bar Cell design, developed by the project core team (Figure 8.1) proposed to combine 21 operations (Figures 8.2) of the GNAT gyroscope family and the grind of the GG4400 family gyroscope (Figure 8.3) in a single integrated area. The "As-Is" flow of these operations through the Fab shop is described in detail in Section 4 of this report. The preliminary design flow is described below.

The preliminary process flow for the GNAT T-Bar was greatly simplified (reference Figure 8.4). Raw material would be delivered to a CNC lathe in the cell. The parts would be heat treated in a batch operation, then returned to the cell for final grind and testing, calibration, and recording of K factor.

The GG4400 stainless steel series T-Bar process would not change substantially. Manual burring would still be completed manually. Improvements in rejection rates would result from improved process documentation provided by Production Engineering and retention of trained operators, by smoothing the work manpower load, in a cell. Two government owned grinders, modified with synchronous drivers, would be reduced to one by providing a quick changeover system for the holding fixtures.

Estimates for the preliminary design labor operations were prepared. They were based on vender supplied time studies, internal estimates using Industrial Engineering approved worksheets, Met Cut published material cutting recommendations, and best engineering judgement. The preliminary design estimates indicated an approximate .69 hour reduction in unadjusted standard labor would result if the project were implemented. Verbal capital equipment cost estimates, received from vendors proposing to furnish the combination machines for the metal removal operations were less than 160K. Volume projections, provided by the Precision Control Instruments business group, varied widely per year.

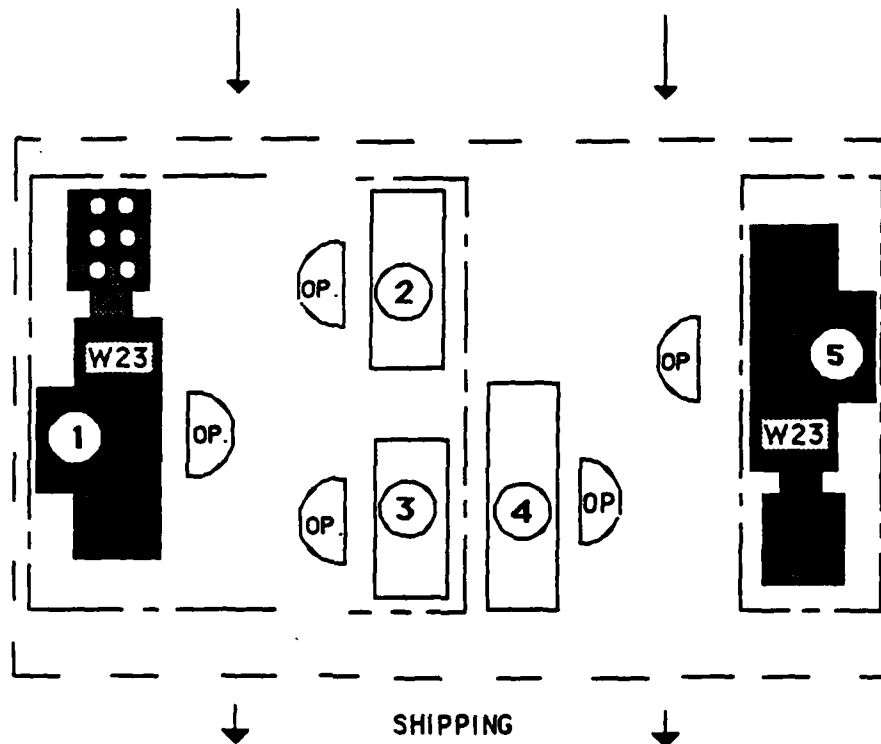
The reductions in direct labor, capital costs and volume projection were used to develop equipment utilization and financial internal rate of return. Both of these were extremely favorable. The proposed cell advanced to final design.

## T-BAR CELL

**AS IS**

RECEIVING FROM  
TURNING DEPARTMENT  
GNAT GYRO ONLY

RECEIVING FROM S/C  
(PURCHASED T-BAR BLANKS)  
GG4400 GYRO ONLY



- ① GRIND WIRE DIAMETER
- ② DE-BURRING
- ③ CHECK " K " FACTOR
- \* ④ DE-BURRING
- \* ⑤ GRIND WIRE DIAMETER

\* GG4400 ONLY

### Figure 8.1 "As-Is" T-Bar Layout

**T-BAR CELL  
AS IS PROCESS FLOW DIAGRAM**

**BERYLLIUM COPPER T-BAR  
GNAT GYRO ONLY**

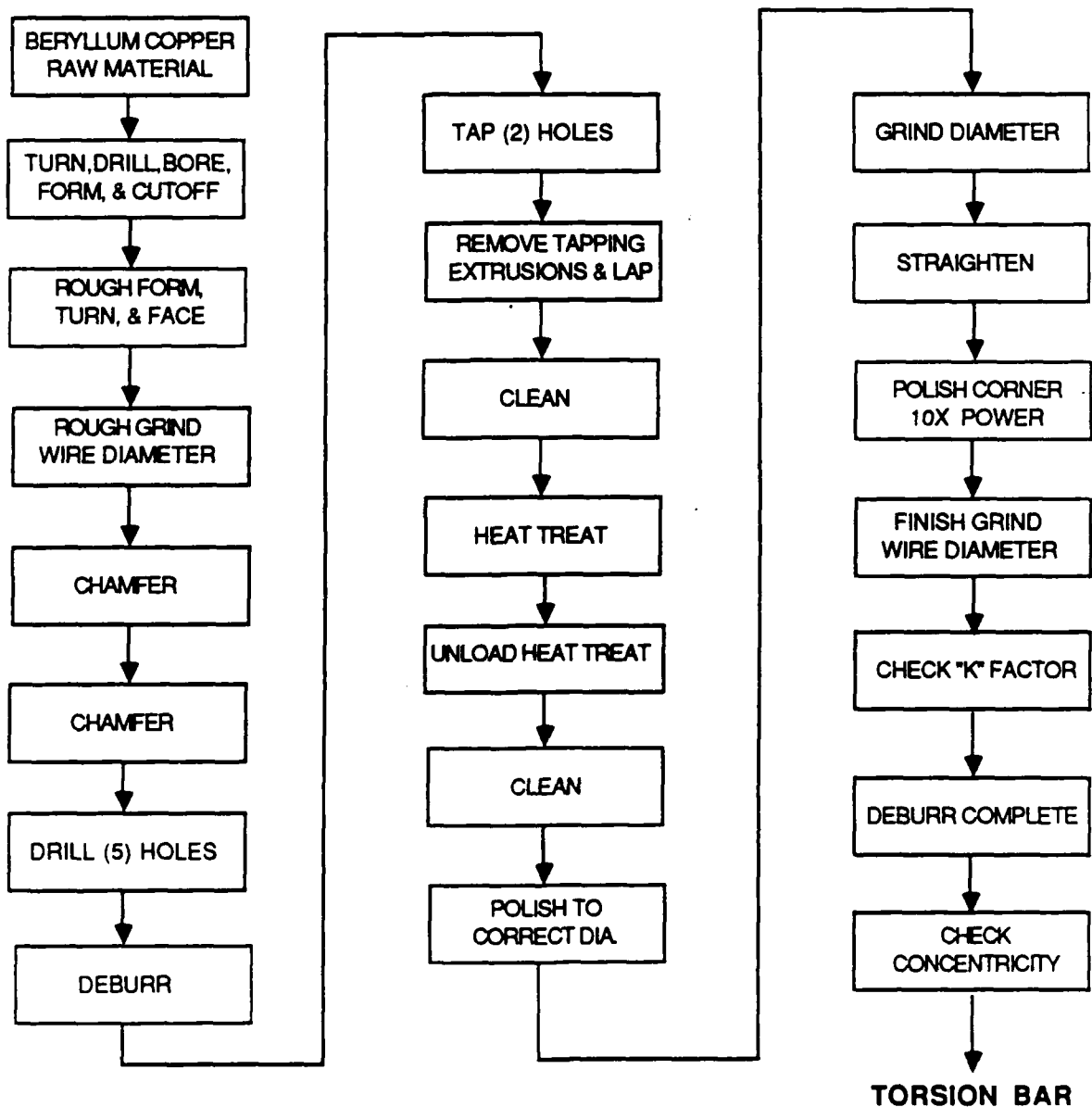


Figure 8.2 "As-Is" Beryllium Copper T-Bar Process Flow

**T-BAR CELL  
AS IS PROCESS FLOW DIAGRAM**

**STAINLESS STEEL T-BAR  
GG4400 GYRO ONLY**

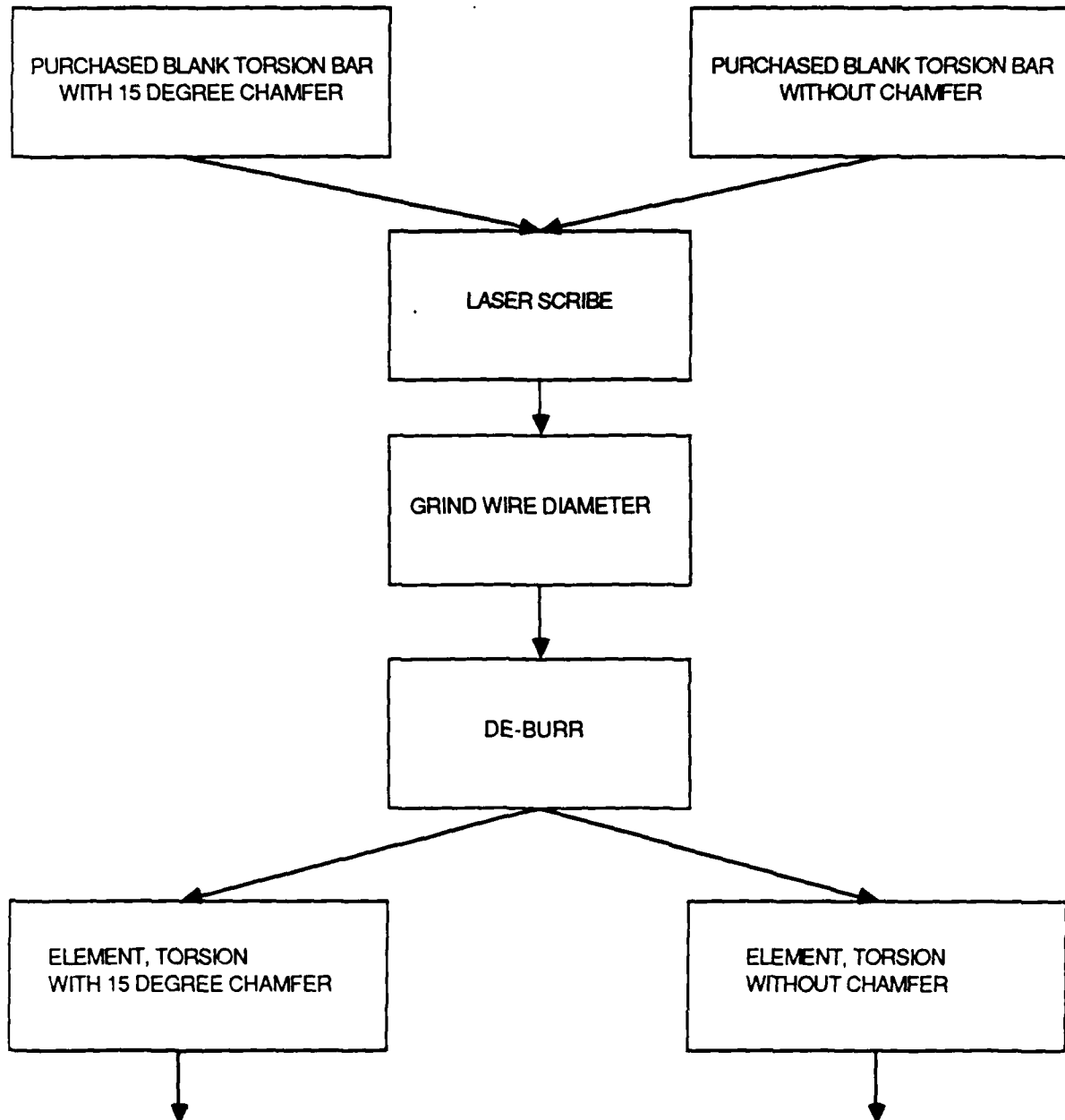
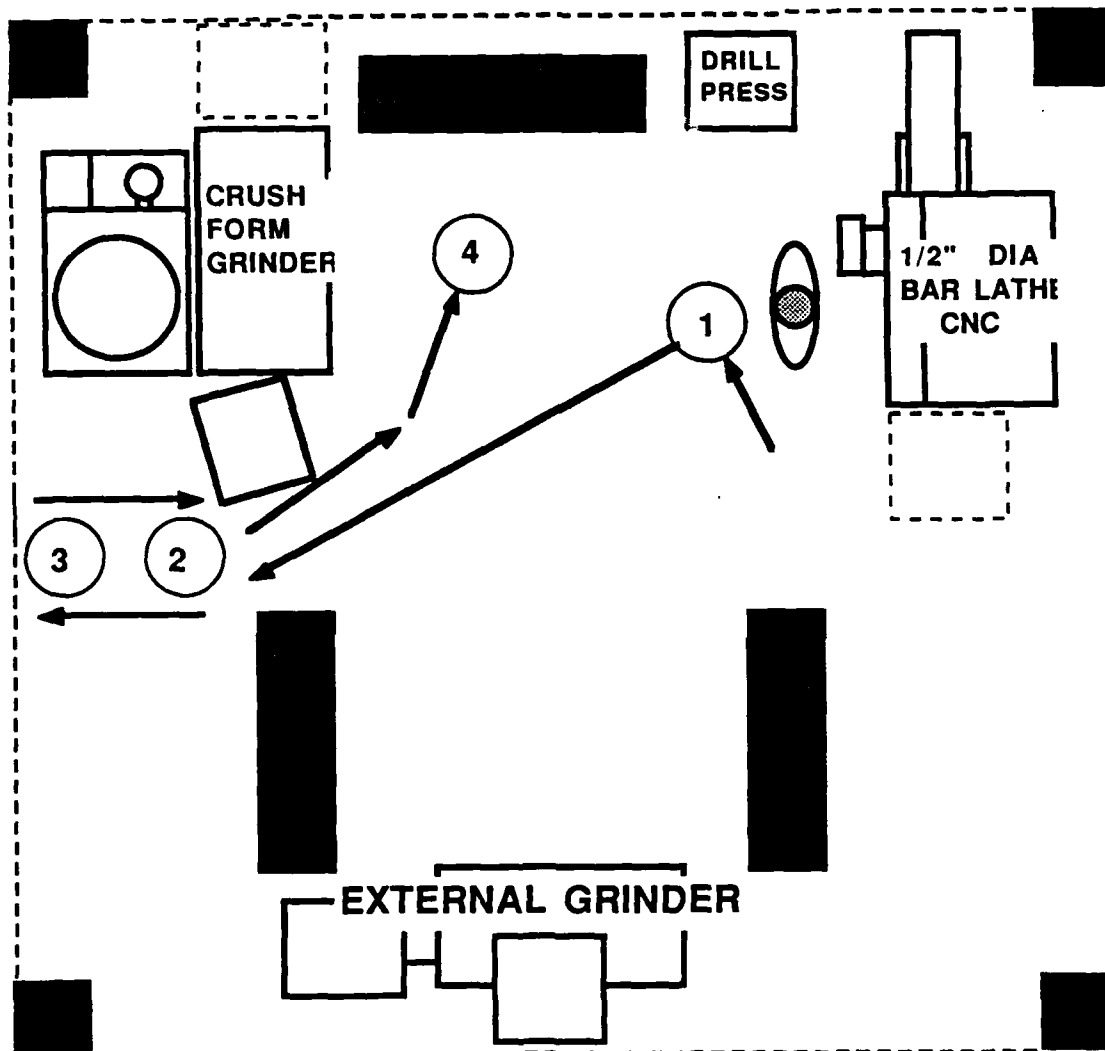


Figure 8.3 "As-Is" Stainless Steel T-Bar Process Flow

**T-BAR CELL LAYOUT AND MATERIAL FLOW  
TO BE  
GG4400 ONLY -- PHASE 2**



1. CUTOFF T-BAR BLANKS
2. HEAT TREAT
3. LASER SCRIBE
4. CRUSH FORM GRIND

Figure 8.4 "To-Be" Stainless Steel T-Bar Material Flow

## FINAL DESIGN AND FINDINGS

Primary changes from the preliminary to final design (Figure 8.5) are the incorporation of a new process for stainless steel T-Bar grinding and elimination of the heat treat operation for the beryllium copper T-Bar.

During the cell analysis, a serious problem of potential gyroscope failure, due to breakage of the stainless steel T-Bar, was discovered. The grinding process left a burr at the intersection of the outside diameter and necked down wire diameter center section of the bar. The area was deburred with a portable jewelers lathe and die file. If the center (wire) section of the torsion bar was touched by the file, a potential fracture area was created. Crush form grinding would, as claimed by machine vendors, eliminate the burr. If the burr did not have to be removed, the variable of operator abilities would be removed as a potential source of field or assembly failure.

### BERYLLIUM COPPER T-BAR

Heat treated, ground bars are supplied to the cell area (Figures 8.6 and 8.7).

The CNC lathe used is the latest design available. It has a Swiss style headstock and bushing for front turning, a rear mounted chuck with a synchronous spindle capable of transferring a cut off part and ejecting a finished part and a turret capable of using tools on either the bar or chuck end. The turret has powered tools to do drilling and tapping operations on the chuck held parts. One drilling operation and removal of all burrs created by the turning machine are completed by the lathe operator as chores, internal to the lathe machine cycle.

The joint effort of grinding the wire diameter, and checking and recording the K factor are as described in the "As-Is" section. The added chore of removal of the grind burr, internal to the testing cycle, has been added to the grinder operators duties.

Electronic feedback from the test equipment to the grinder may still be a future consideration. It was not included in the final design due to the need to replace the manual grinder with a CNC operated machine. A preliminary analysis indicated the upgrade to the tester and the purchase of a new grinder would be cost effective.

### STAINLESS STEEL T BAR

Stainless steel bars are delivered to the work cell. Batch processing is used to produce turned, unground blanks (Figures 8.4 and 8.5). The blanks are then chamfered per order requirements. The blanks are heat treated in Fab and laser scribed in either the PCI's laser welder or Fab's Girth Ring Cell laser welder as scheduled by the CRP module of HMS.

The blanks are crush ground to both the large diameter, wire diameter and neck radius simultaneously. The process does not leave a burr or create potential stress fault lines that could result in assembly or field failures.

T-BAR CELL  
TO BE PROCESS FLOW DIAGRAM

STAINLESS STEEL T-BAR  
GG4400 GYRO ONLY

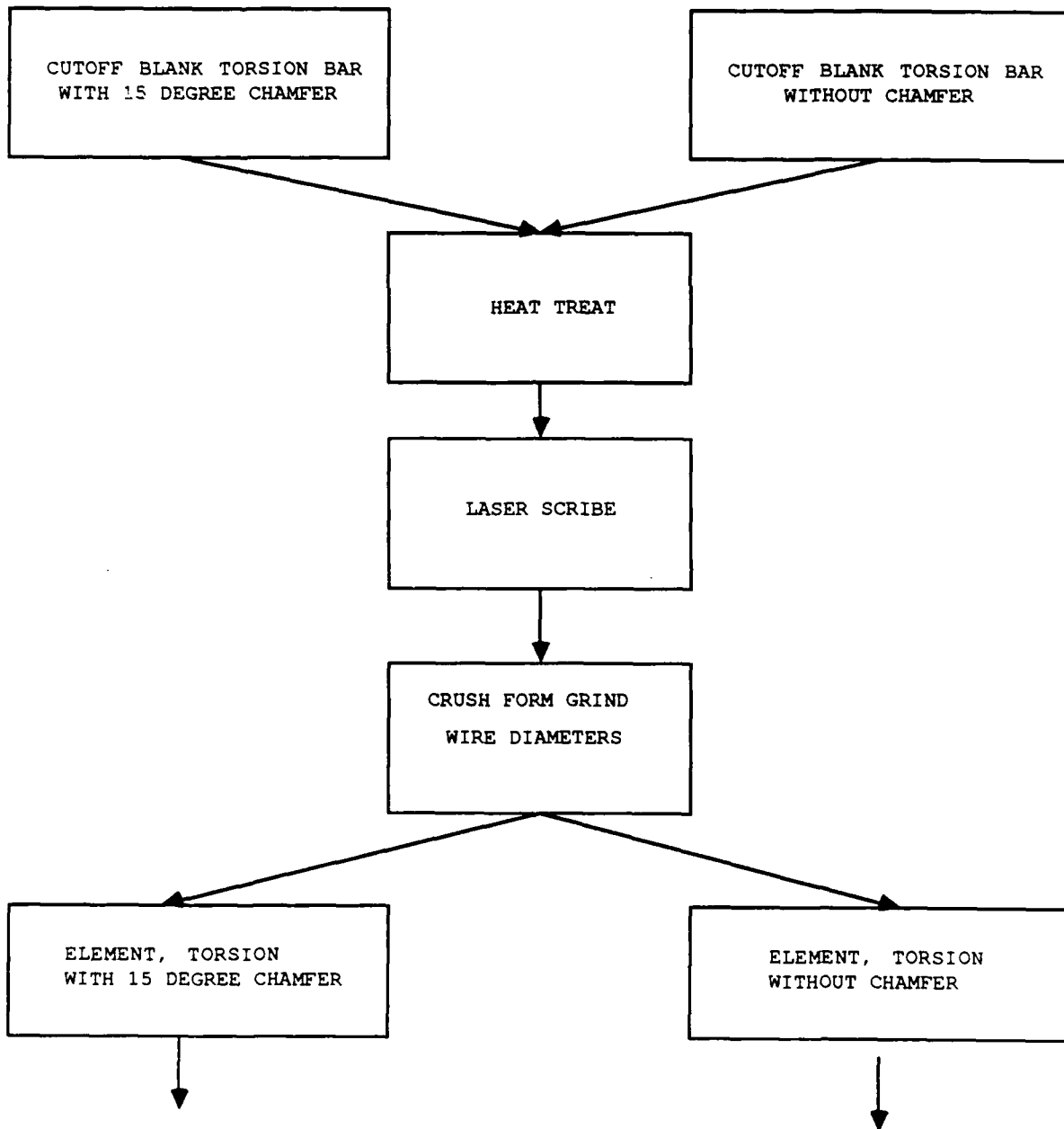
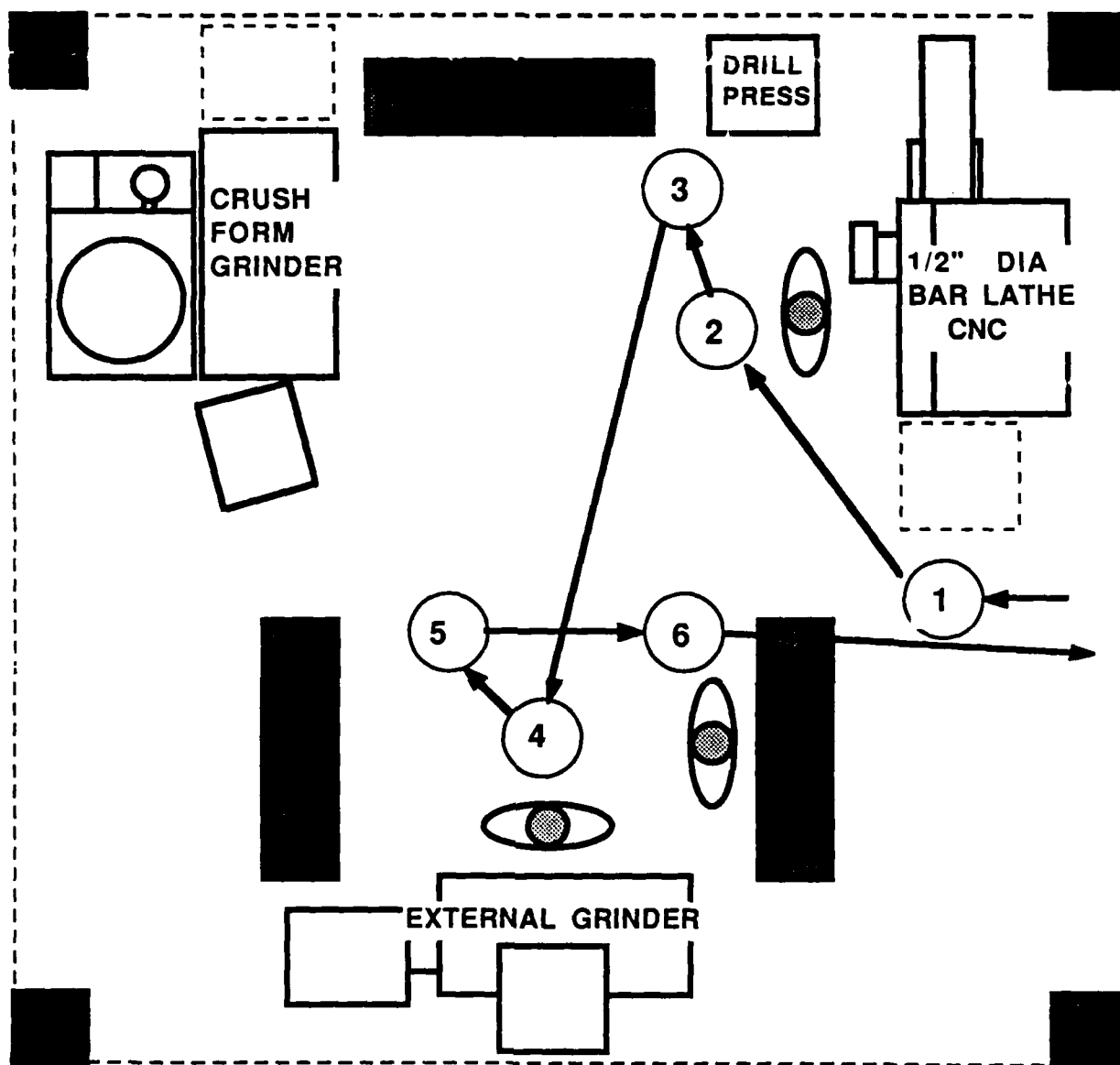


Figure 8.5 "To-Be" Stainless Steel T-Bar Process Flow



# **T-BAR CELL LAYOUT AND MATERIAL FLOW TO BE GNAT ONLY -- PHASE 2**



- |  |                     |
|--|---------------------|
| 1. HEAT TREAT (BAR)                      | 4. GRIND WIRE DIA.  |
| 2. MACHINE COMPLETE                      | 5. DE-BURR          |
| 3. DRILL .025 DIA. (SECONDARY OPERATION) | 6. CHECK "K" FACTOR |

Figure 8.6 "To-Be" Beryllium Copper T-Bar Cell Layout and Material Flow

**T-BAR CELL  
TO BE PROCESS FLOW DIAGRAM**

**BERYLLIUM COPPER T-BAR  
GNAT GYRO ONLY**

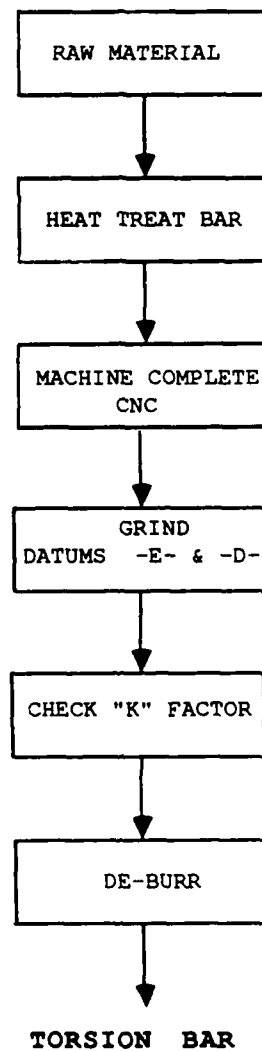


Figure 8.7 "To-Be" Beryllium Copper T-Bar Process Flow

#### CNC LATHE - 1/2" DIAMETER

Excess capacity on the 1/2" diameter lathe is shared with the Flexible Machining Area. It acts as a buffer to workloads on the 1 1/2" Bar process line. Operators for the lathe are shared with the Flex Shop area.

#### CONCLUSION OF PROJECT - DECISION TO NOT IMPLEMENT

When firm volumes for project use were defined, they were substantially reduced from original PCI projection. It was also noted the GNAT (beryllium copper) T-Bar would be discontinued in two to three years. A requote by the crush grind equipment vender resulted in a major price increase. The exchange rate between the dollar and the Swiss franc was said to have been a substantial contributor to the quotation increase.

The cost effectiveness and equipment utilization was reexamined. The project did not meet internal thresholds for either test. The project was concluded. Subcontracting of the stainless steel torsion bar, by a crush form grinding vendor is being analyzed.

## SECTION 9

### SYSTEM/EQUIPMENT/MACHINING SPECIFICATIONS

#### CRUSH FORM GRINDER

The following specifications must be met by the vendor or internal Honeywell Department to manufacture the crush form grinding machine. The machine must complete the part in one operation. Crush form tooling rolls, automatic part load/unload devices and demonstration of the machine to meet all print dimensional requirements and quoted production rates must be demonstrated prior to acceptance of machine by Honeywell.

#### Machine specifications:

- Workpiece diameter, minimum - .010"
- Workpiece diameter, maximum - .200"
- Maximum plunge ground length - 1.500"
- Plunge grinding attachment
  - Total stroke - .200"
  - Work stroke - 0 to .200"
  - Rapid approach and return feed - .800" per second
  - Work feed stepless - .00008" to .020" per second
- Spindle speeds
  - Grinding wheel - 4500 RPM
  - Control wheel stepless - 20 to 145 RPM
  - Control wheel dressing - 455 RPM
  - Outside diameter of grinding wheel - 6"
  - Inside diameter of grinding wheel - 1.980"
  - Outside diameter of control wheel - 4"
  - Inside diameter of control wheel - 1.580"

#### CNC TURNING MACHINE

The following specifications must be met by the vendor or internal Honeywell Department which bids to manufacture the CNC bar machine.

The CNC (Computer Numerical Control) bar machine must be capable of machining bar stock to a minimum capacity of 1/2" and must be equipped with the necessary attachments to perform secondary and cutoff end machining operations on the beryllium copper T-Bar. This does not include the .100 millimeter diameter hole and final grind operations as detailed in the process flow diagram Figure 8.8 of this report. Special tooling and demonstration of the machine to meet all print dimensional requirements and quoted production rates for the beryllium copper T-Bar must be demonstrated prior to acceptance of machine by Honeywell.

Machine specifications:

- Minimum outside diameter - .500"
- Maximum guide bushing travel/chuck - 4.920"
- Number of tools - 10
- Spindle speeds - 333~9,999 RPM
- Tool dimensions - 3/8" square x 2.36" long
- Minimum input - .0001"

## SECTION 10

### TOOLING SPECIFICATIONS

The following tooling specifications must be met by vendor or internal Honeywell Department which bids or purchases tooling for CNC (Computer Numerical Control) crush form grinding machine.

Tooling specifications (to be vendor supplied):

- Profile dressing by diamond roller and crushing.
- Automatic dressing of grinding wheel by diamond crush roll.
- Automatic loading attachment for through and plunge of extremely small diameters.
- Balancing attachment with balancing arbor.
- Tungsten carbide workplates.

The following tooling specifications must be met by vendor or internal Honeywell Department which bids or purchases tooling for 1/2" bar CNC (Computer Numerical Control) machine.

Tooling specifications:

- None - Industry standard cutting tools and holders will be used.

## SECTION 11

### VENDOR/INDUSTRY ANALYSIS/FINDINGS

The CNC (Computer Numerical Control) crush form grinding and CNC bar machines were evaluated as follows:

The first choice was the AGATHON Model 150 SL 2 CNC (COMPUTER NUMERICAL CONTROL) crush form grinder. The AGATHON grinder has the capability for the required tolerances and has a parts feeder.

For a second or alternate selection, a ROYAL MASTER Model DRF-12X3 was selected which would contain a programmable control. Parts are manually magazine loaded and each operation must be performed separately.

The CNC (Computer Numerical Control) crush form grinding machines considered must have the following capabilities:

- Grind O.D.
- Chamfer.
- Recess.
- Automatic load and unload.
- Grinding time complete, approximate 1 minute per part.

Concerns: Tolerance must be held within  $\pm .0002"$

Findings: CNC crush form grinding machine features assure tolerances:

- Free of vibration due to modal analysis of vibrations and systematical optimization.
- Sturdy and accurate hydro-pneumatic plunge feed unit with single or double rapid feed.
- Control and grinding wheel spindle are equipped with high precision pre-loaded bearings.

Concerns: Setup and wheel dressing must be quick and easy.

Findings: Machine was designed in view of easy setup.

#### Dressing of grinding and control

- The profile is directly copied from the template. The hydro-pneumatic dressing motion is executed on play-free roller slides.

#### Profile dressing of the grinding wheel by a diamond dressing attachment

- Suitable for accurate dressing of complex profiles.
- Special interest for small batch production, such as molding ejectors.

#### Profile dressing by diamond roller and crushing

- The profile dressing of carborundum wheels is executed by diamond rollers and the profile dressing of special bonded diamond wheels by crushing.

Concerns: Machine must be fully automatic including the load and unload parts.

Findings: The time involved in placing workpieces in fixtures, as well as costly centering operations for mounting between centers are eliminated.

- The simplified loading and unloading of the workpieces permits the use of automatic loading systems. This is mostly impossible with other grinding methods.
- Supporting the workpiece over its whole length allows increased feed rates and, as a result, shorter grinding times.
- Automatic loading attachment for through and plunge grinding of extremely small diameter parts, such as dotting pins, from 0.3mm (.012") diameters and length up to 100mm. The plunge grinding including:
  - Funnel magazine with separator belt conveyor for through grinding and interchangeable pneumatic infeed cylinder for Marposs Inprocess gauging system (or equivalent).
- Grinds complete part in one operation.

#### THE 1/2" BAR CNC (COMPUTER NUMERICAL CONTROL) MACHINE

The 1/2" bar CNC machine must have the ability to complete a part in one operation including:

- Turning.
- Drilling.
- Cross-drilling.
- Slotting.
- Milling.



Rotation of second operation tool:

- Drilling.
- Slotting cutter.
- Milling cutter, etc.

Concerns: Must have capability for flexible, economical production in small and large batches.

Findings: Optical tool presetter is prepared for easy and accurate presetting.

- The CNC automatic lathe, not only handles repeat short run production but is also capable of high productivity comparable to conventional cam type automatic lathes.

Concerns: Should have capability for machining the cutoff side instead of a second chucking operation.

Findings: The 1/2" bar CNC machine fulfills that requirement. The main spindle indexing can be accomplished in one set-up in addition to turning, which enables a complete work piece to be produced in one operation.

Concerns: Machine must produce parts that are consistently accurate within  $\pm .0002"$ .

Findings: High turning accuracies are achieved by the use of a unique sliding guide bushing mechanism. The guide bushing is used for maximum workpiece support. The guide bushing enables minimum material deflection and greatly improved turning accuracies. It also eliminates the negative effects of thermal expansion, which is the major cause of dimensional fluctuations.

Concerns: The CNC programs must not be complicated.

Findings: Program features found were:

- Built in monitoring systems.
- Compatibility with host FMS computers.
- Ease of programming similarity to present system will pose less difficulty for programmers and operators.
- The 20K capacity accommodates background editing, allowing the operator to modify stored programs while the machine is in operation.

The first choice was the CITIZEN Model CINCOM F-12 Lathe, it was chosen because it meets our requirements for accuracy, capability and cost.

**T-BAR CELL**  
**EQUIPMENT SEARCH FORM**

CELL NAME: T- BAR CELL

**TECH-MOD PROJECT #44**

GENERIC EQUIPMENT SPECIFICATIONS:

CNC (COMPUTER NUMERICAL CONTROL) CRUSH FORM GRINDING (CENTERLESS)

AND

CNC (COMPUTER NUMERICAL CONTROL) TURNING SMALL DIAMETER (1/2" DIA.)

EQUIPMENT & VENDOR	REQUESTED INFO. SENT	RESPONSE	EQUIPMENT DESCRIPTION	REMARKS
AGATHON PRODUCTIVITY, INC	YES	YES	AGATHON 150-SL2 GRINDER CNC CONTROL	QUOTATION & TIME ESTIMATES WERE RECEIVED.
ROYAL-MASTER MARTIN MACH.	YES	YES	ROYAL-MASTER GRINDER MODEL DRF-12X3 PROGRAMMABLE CONTROLLER- NOT CNC	QUOTATION & TIME ESTIMATES WERE RECEIVED.
DANOBAT ANDERSON MACH.	YES	YES	MODEL M2100 GRINDER	
CINCINNATI	YES	NO	N/A	N/A
CITIZEN ELLISON MACH.	YES	YES	MODEL CINCOM F-12 LATHE SWISS-STYLE TURNING CENTER	QUOTATION & TIME ESTIMATES WERE RECEIVED.
STAR Q & S MACHINE	YES	YES	MODEL VNC-20 LATHE SWISS-STYLE TURNING CENTER	QUOTATION & TIME ESTIMATES WERE RECEIVED.
MOMURA HALES MACHINE	YES	YES	MODEL NN-12 K LATHE SLIDING HEADSTOCK	QUOTATION & TIME ESTIMATES WERE RECEIVED.

Figure 11.1 T-Bar Cell Vendor Analysis

## SECTION 12

### EQUIPMENT/MACHINERY ALTERNATIVES

Due to the complexity of the manufacture of these piece parts, there is no suitable alternative equipment. In-house manufacturing capability is essential for product development, cost stability and delivery assurance.

Modern precision machines are required to maintain this capability. At present, parts are produced on 20 year old government-owned equipment. If, for any reason, the equipment fails, we will be forced to subcontract the building of the parts at a substantially increased cost.

## SECTION 13

### MIS REQUIREMENTS/IMPROVEMENTS

There are no Management Information System requirement or improvements required, other than those discussed in Section 13 of the Project Overview.

## SECTION 14

### COST BENEFIT ANALYSIS

NO CBA IS INCLUDED IN THIS REPORT SEGMENT

Based on the final design, the cost savings resulting from the use of the new machines would not justify the capital investment. The equipment also does not meet internal utilization requirements. Parts discussed in this report segment are included in the Model/Short Run/Flexible machining segment of this Final Report.

## SECTION 15

### IMPLEMENTATION PLAN

No implementation plan is included in this report segment. The cell was concluded, prior to plan development, since it did not meet internal requirements for equipment utilization and return on investment.

## SECTION 16

### PROBLEMS ENCOUNTERED AND HOW RESOLVED

No special problems were encountered other than those described in Section 16 of the Project Overview.

## SECTION 17

### AREAS FOR FUTURE CONCERNS/DEVELOPMENT

This project will be reexamined for changes in economic or business developments that may cause the project to be rescheduled for implementation. If the project is re-opened, the economics in providing electronic feedback from the beryllium copper T-Bar "K" value tested to a CNC machine grinding, the wire diameter will be reexamined.